COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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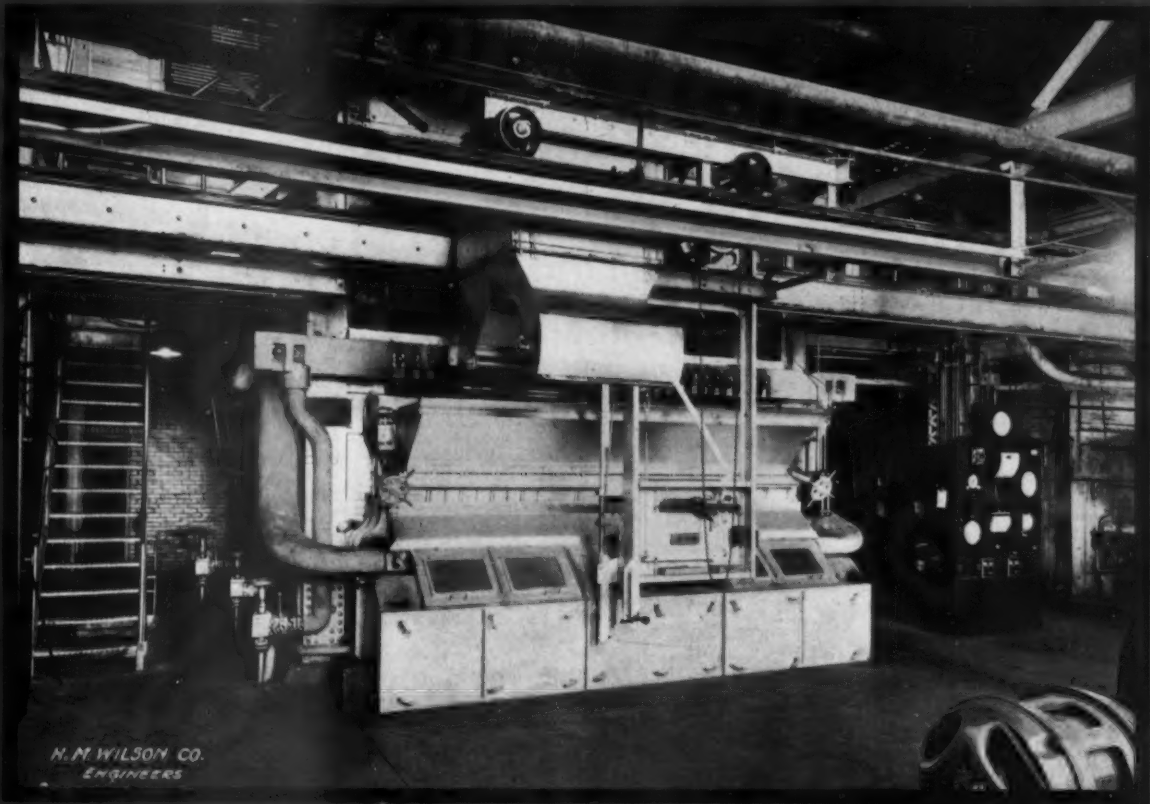

Traveling-grate stoker under a 100,000 lb per hr, 600-lb pressure boiler at Container Corporation of America, Carthage, Ind.

Port Washington's Second Year

Superheaters for High-Temperature, High-Pressure Service

Operating Experiences at Burlington Station

RCA effects Large Economies by Modernizing with C-E equipment

Pulverized coal is supplied by four C-E Raymond Bowl Mills

Faced with the dual problem of increased steam demand and an inefficient steam plant, RCA Manufacturing Company, Inc., found an ideal solution in the purchase of 2 C-E Steam Generating Units.

These new units, the arrangement of which is shown at the right, supply 125,000 lb of steam per hr each at 850 lb pressure and 750 F total temperature. They serve two new high pressure turbines which drive existing generators and function as a superposed application in connection with other serviceable equipment of the existing plant.

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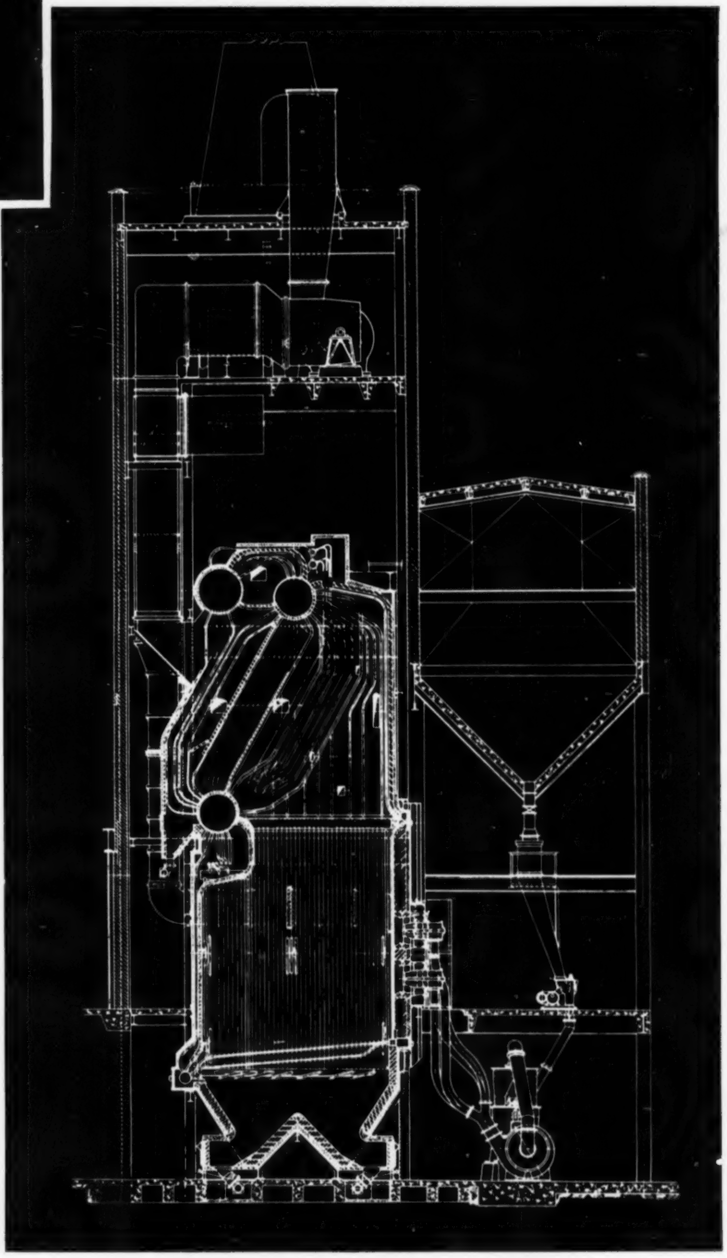

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ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS, STOKERS; ALSO SUPERHEATERS, AIR HEATERS AND ECONOMIZERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINE NUMBER EIGHT

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FOR FEBRUARY 1938

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EDITORIALS

DEPARTMENTS

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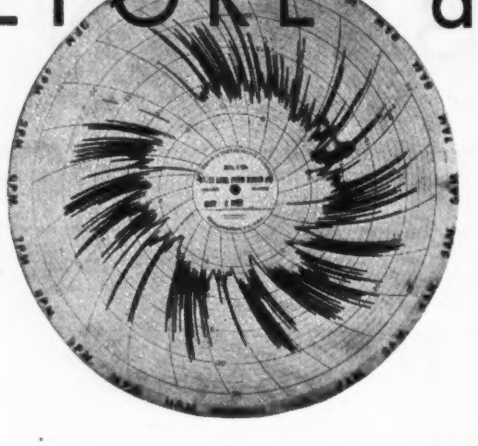
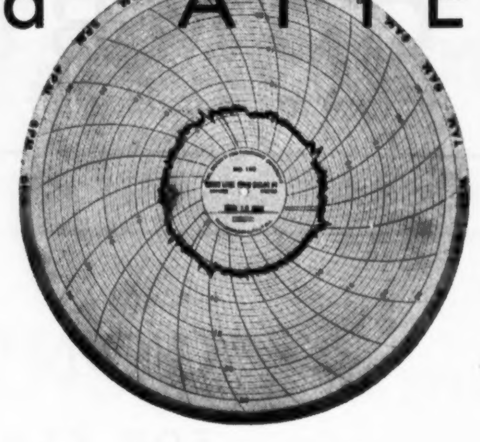
"BEFORE" and "AFTER"





Charts prove value of steam-flow type COPES *feed water control*

Compare these water level recorder charts taken from the same boiler under similar load conditions. Note how the water level fluctuations were reduced from 15 inches to 3 inches by a COPES steam-flow type feed water regulator. Unusual? By no means. There are more than 100 installations where you can check the results. Write for Bulletin 409-A describing the new two-element COPES Flowmatic Feed Water Regulator.

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FEEDS BOILER ACCORDING TO STEAM FLOW•AUTOMATICALLY

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EDITORIAL

Undistributed Profits Tax Affects Engineers

Engineers are often accused of sticking too closely to their professional problems to the exclusion of the many broader economic questions that affect their well-being—questions that they are exceptionally fitted to analyze but which they complacently leave to the politicians. Never before has there been greater need for straight thinking on such matters.

The philosophy of the New Deal has furnished many such problems among which looms the much-debated undistributed profits tax, abandonment or modification of which is now being urged upon Congress by many business groups.

The idea underlying this tax was to force more money into circulation by making it expedient for companies to declare larger dividends rather than to divert a substantial portion of profits to the building up of reserves. By thus providing a wider distribution of profits it was believed that purchasing power would be increased and, incidentally, that an appreciable part would revert to the Government in the form of individual income taxes. Superficially the proposal appeared to have some merit, despite many protests at the time of its enactment. It was expected to aid more directly the consumer goods industries—a class that suffered least during the period from 1930 to 1934—although it tended to penalize the heavy goods industries whose prosperity, in general, is dependent on new capital, or the reinvestment of surplus accumulated from profits. While many companies chose to distribute a larger portion of their earnings as dividends in preference to paying larger taxes, the present recession is evidence that the tax has failed in its essential objective of increasing purchasing power. Moreover, it has resulted in lesser reserves with which to combat the recession.

Few people depend upon dividends for their livelihood and those more fortunate individuals with large vested interests are prone to invest their dividends in tax-exempt securities. The great majority are dependent upon wages or salaries which, in the final analysis, rests upon a healthy growth of industry. This involves capital to provide manufacturing facilities to meet ever-changing needs, for research and development, and for the replacement of obsolete and depreciated equipment. The building up of adequate reserves for these purposes is preferable to borrowing, with its attendant risk of outside dictation to management.

Many examples could be cited of successful establishments, forming landmarks in our industrial structure, which have been built up entirely through accumulated reserves and which provide employment to thousands of workers. Under the undistributed profits tax, had it long been in effect, the phenomenal growth of some of these companies would have been impossible, and it is most unlikely that they would have been such important factors in contributing to the advances in industrial power plant practice such as exist today.

Employment and progress in the engineering field, particularly that of mechanical engineering, are definitely dependent upon activity among the capital goods industries, as has been shown by numerous surveys. To the extent that the undistributed profits tax tends to stifle such activity the welfare of engineers is directly jeopardized and they should be among the first to realize it.

Freight Train Lengths vs. Power Costs

A bill proposing to reduce and limit the length of freight trains has been before Congress for some weeks. Just how its passage would affect power plants may at first glance seem obscure, but it would nevertheless have a very definite bearing on power generation costs.

Shorter trains mean more trains. This, in turn, means higher carrying charges for the freight due to increased labor costs, more locomotive fuel and added fixed charges on the greater amount of equipment required. Since coal forms a major part of rail shipments it would bear a proportionately large part of the increased carrying costs. It is inevitable that still higher tariffs than those now being sought by the railroads would result and these would mean higher coal prices to the consumer.

The bill is understood to have been sponsored by labor with the ostensible object of promoting greater safety to freight train crews, but with the thinly-veiled purpose of providing more jobs. It requires no imagination to perceive that the greater number of trains would multiply the hazard at every grade crossing and lessen the safety of passenger travel on the railroads, especially those already operating on close schedules. As a matter of fact, statistics reported by the Interstate Commerce Commission indicate a consistent reduction in railroad accidents over the past fifteen years during which period freight train lengths have steadily increased.

From the standpoint of the railroads, the present efficiency of mass freight movement would be seriously impaired, but the power engineer is concerned primarily with power costs. The increase in coal prices resulting from the operations of the Bituminous Coal Act of 1937 is already being felt by both utilities and industrial plants. To increase this burden still further by higher freight rates would offset many of the economies brought about by engineering efforts during the past few years.

The bill, which has passed the Senate, is now in the hands of the Committee on Interstate and Foreign Commerce of the House of Representatives and every effort should be made to forestall action upon it until the views of those likely to be affected are given full consideration.

PORT WASHINGTON'S

By M. K. DREWRY

Assistant Chief Engineer of Power Plants
Milwaukee Electric Railway & Light Co.

With half of its two years of operation spent in three continuous runs, all ending with scheduled inspection outages, this reheat plant, consisting of a single boiler and turbine-generator operating at 1300 lb 825 F, evidences high reliability. To date it has operated 86 per cent of the time since the month of "tune-up," with an availability of 88.7 per cent. Extremely rapid corrosion in the absence of oxygen that caused a new 3/8 in. thick tube to fail in five days temporarily interfered with reliability until a definitely corrective treatment, involving the establishment of natural protective films when guided by hydrogen measurement, was applied. The first year's average heat consumption of 10,954 Btu per net kwh was slightly improved by a 10,835 Btu average for 1937.

THE common expression, "The plant is the laboratory," reflects the attitude of the power industry which has prompted increasingly complete reporting of power station experiences in this country. To the free exchange of operating information is undoubtedly creditable a portion of the current rapid developments.

The first year's operation of the Port Washington station was reported in November 1936 in an A. S. M. E. paper by F. L. Dornbrook.[1] The present article is arranged to bring that report up to date, treating subsequent experiences chronologically and comparing 1937 data with those of 1936.

Boiler Corrosion Experience

An unusual type of internal water-tube corrosion, never encountered in the extensive Lakeside experience with nearly identical equipment, became acute in December 1936. Four week-end outages were necessary to replace thinned water-screen tubes, which were revealed when "sounding" the furnace.

Corrosion, despite the positive absence of oxygen in the feedwater, thinned new $^3/_8$-in. thick tubes to the point of leaking between Monday and Friday, December 21 and 25, and emphasized the extreme importance of natural protective tube coatings. For all screen tubes to operate successfully nearly a full year, and then suddenly to have replacement tubes fail in five days, indicated that neither design nor small differences in operating procedure were responsible.

Progress in correcting the trouble while operating was first attained when the importance of protective films was recognized. How to establish them reliably and how to be assured of their effectiveness without having to wait for further failures, prompted a rapid and intense search for a test method that would evaluate the instantaneous corrosion rate.

The application of corrective measures was further encouraged by occurrence of the first enforced outage that was experienced by the plant. On Tuesday, January 12, 1936, a thinned tube suddenly developed a leak of $2^1/_2$ sq in. area which necessitated prompt outage. During the ensuing outage of 13 days, all questionable screen tubes, totaling 66, were replaced.

TABLE 1

OPERATING PERIODS AND REASONS FOR OUTAGES
Since Starting Normal Operation November 22, 1935

Period No.	Date: Started	Date: Finished	Hours Run	KWH Generated	Outage: Hours	Outage: Reason
5-15*	Nov.22,1935	July 3,1936*	4,735*	233,489,500	701.1*	Inspection, lack of load and maintenance.*
16	July 6,1936	Oct. 3,1936	2,155	119,006,000	223.3	General Scheduled Inspection
17	Oct.13,1936	Nov. 7,1936	608.67	33,990,000	54.72	Replaced turbine equalizer pipes, scheduled.
18	Nov. 8,1936	Nov.20,1936	259.53	15,198,000	4.52	Condenser tube breakage.
19	Nov.20,1936	Nov.21,1936	12.45	969,000	36.45	Tightened bolts, turbine main joint.
20	Nov.22,1936	Dec. 4,1936	281.53	16,363,000	54.36	Tube corrosion.
21	Dec. 7,1936	Dec.17,1936	256.98	15,077,000	79.40	Tube corrosion.
22	Dec.21,1936	Dec.27,1936	136.57	7,552,000	54.73	Tube corrosion.
23	Dec.28,1936	Jan. 3,1937	90.17	5,868,000	32.63	Tube corrosion.
24	Jan. 4,1937	Jan.12,1937	195.93	11,020,000	307.27	Tube corrosion, low pressure turbine repair.
25	Jan.25,1937	Mar.14,1937	1,146.67	63,262,000	447.93	General scheduled inspection, high pressure turbine inspection.
26	Apr. 1,1937	Apr.10,1937	222.57	11,197,000	31.15	To improve turbine balance.
27	Apr.12,1937	Apr.19,1937	136.73	7,683,000	31.47	Lack of load.
28	Apr.19,1937	Apr.24,1937	136.52	7,500,000	31.23	Lack of load.
29	Apr.26,1937	May 1, 1937	135.93	7,396,000	31.73	Lack of load.
30	May 3, 1937	May 8, 1937	136.18	7,292,000	28.25	Lack of load.
31	May 10,1937	May 15,1937	139.83	7,403,000	28.53	Lack of load.
32	May 17,1937	May 22,1937	139.53	7,465,000	28.58	Lack of load.
33	May 24,1937	May 27,1937	91.55	5,000,000	100.85	Lack of load, and pipe joint repair.
34	June 1,1937	July 16,1937	1,037.97	61,760,000	.43	Error
35	July 16,1937	Oct. 2,1937	1,856.80	106,064,000	216.57	General scheduled inspection.
36	Oct. 10,1937	Dec.26,1937**	1,847.50	99,886,000	**	
Total	Nov. 22,1935	Dec.26,1937	15,811.25	850,659,500	2543.81	

*See Mr. F. Dornbrook's A.S.M.E. paper in November, 1936, Mechanical Engineering for a detailed record of first 15 operating periods.

**Still in operation.

Protective Films

Volumetric measurement of a few hundred cubic centimeters per hour of hydrogen, concentrated from a 10 ton-per-hr steam sample (0.05 cc per liter), regularly condensed in a high-pressure extraction heater, indicated an iron corrosion rate of at least 3 lb per day be-

[1] See *Mechanical Engineering*, November 1936.

SECOND YEAR

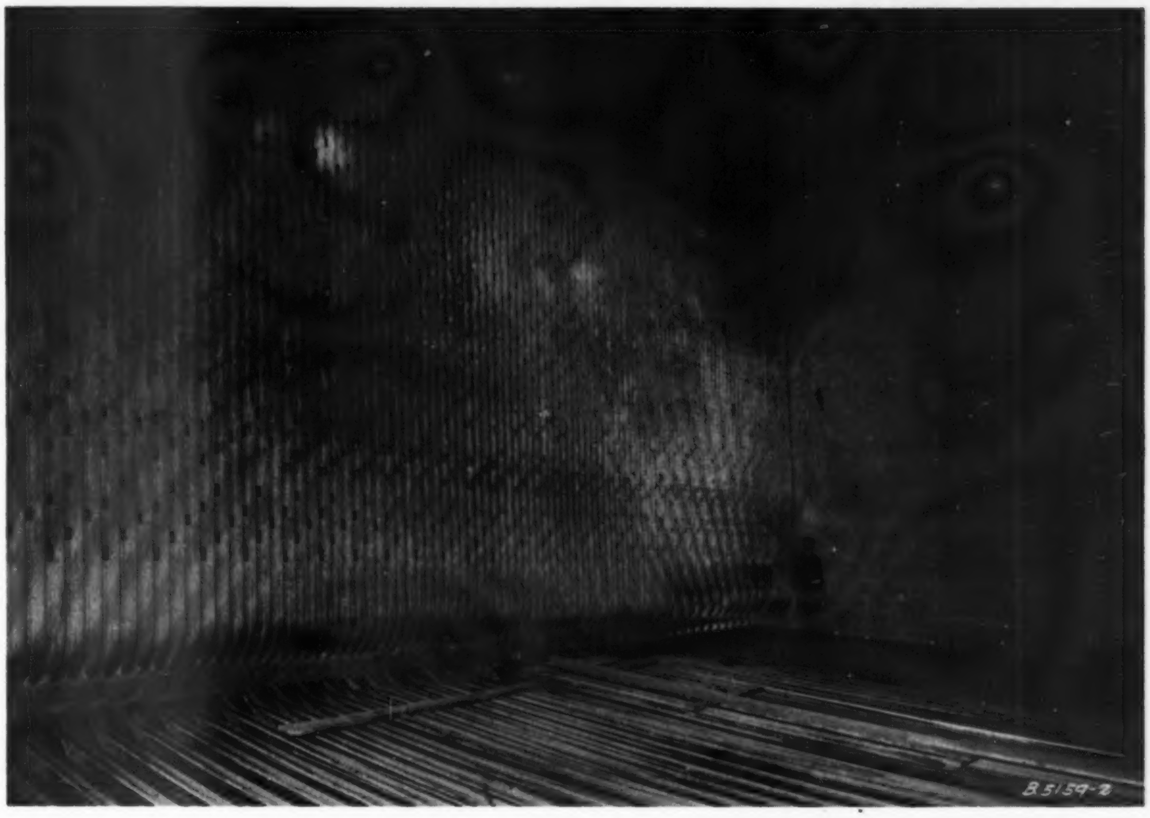

Fig. 1—A nearly self-cleaning furnace

Only light ash on the water-screen tubes is cleaned manually. The first row of boiler-tubes has required lancing on only one occasion.

fore effective coating methods were determined. The initial coating trial, consisting of the deposition of calcium sulphate scale of controlled magnitude, proved ineffective immediately. Resumption of normal sodium phosphate concentrations was accompanied by a large reduction in the hydrogen rate simultaneously with phosphate charging. Since observations showed that the effect of phosphate depreciated between chargings, more phosphate was fed, at more frequent intervals, causing higher phosphate concentrations and noticeable turbine clogging.

Though the newly installed tubes were boiled out at atmospheric pressure with a concentrated phosphate solution before being placed in operation, hydrogen evolution persisted after the January outage. Phosphate often did not prove entirely effective, and on some occasions in February the hydrogen rate was not at all responsive to heavy phosphate charges. High excess air, high flame position and low loads were frequently ineffective.

Low Alkalinity

On many occasions, the lowest hydrogen occurred when the boiler water alkalinity was lowest. The previous standard of 30 ppm phenolphthalein alkalinity, increased to 200 ppm for trial, was gradually reduced to 20 ppm, to help obtain the lowest corrosion rates, and now 6 ppm is averaged.

Study suggested the corrosion to be of an electrochemical nature, and indicated the possibility that an oxide film might be formed on the area where phosphate was ineffective. Experience of the electrochemical industry shows that permanent oxide coatings are formed on iron electrodes operating at high current density. In this case, establishment of an oxide coating was attempted early in March by departing from the Lakeside practice of normally maintaining an excess of the oxygen reducing agent in the boiler feedwater. Immediate reduction of the corrosion rate to a few ounces per day accompanied the absence of an excess of oxygen-reducing agent in the boiler feedwater. Several subsequent observations proved unquestionably the desirability of non-oxygen-reducing feedwater.

March 1937 Inspection

When the equipment was deliberately removed from service for boiler and high-pressure turbine inspection, three screen tubes in the center of the corrosion attack were removed and dissected for careful internal inspection. All were found free from measurable corrosion.

Careful inspection showed the presence oi two kinds of coatings at the top of the tubes where corrosion had previously occurred. A $^3/_8$-in. wide straw-colored coating at the extreme top was apparently the oxide coating, the last to be established. Adjacent to it on both sides

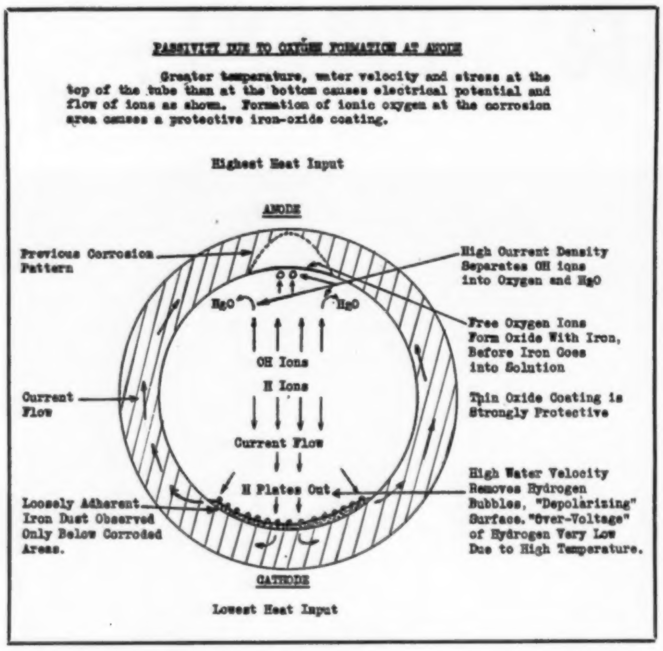

Fig. 2—One theory of unusual corrosion mechanism

Oxygen in the high-pressure boiler feedwater usually causes the common type of oxygen corrosion, but in the rarer case of extremely rapid corrosion in the absence of feedwater oxygen, oxygen formation electrolytically near the corroding area may cause a valuable protective oxide coating. This experience indicates that high-pressure boiler water should be of very low alkalinity and of a non-oxygen-reducing nature; essentially neutral in both respects.

was the initially-established iron-phosphate coating. The remainder of the tube periphery was covered with a darker, tightly adherent coating. Table 6 gives analyses of samples removed with a scraper. That all three coatings were positively impenetrable to electrolytic attack was proved by non-deposition of copper during test with copper-sulphate solution. The oxide film, unlike the phosphate coating, was extremely thin and could be readily broken with slight pressure of a sharp tool.

Theory of Corrosion

Fig. 2 represents a seemingly plausible explanation of the corrosion mechanism in this case. Right or wrong, this theory agrees with all experiences of the case, and treatment methods based upon it have definitely stopped subsequent trouble. A fourth tube removed for inspection in October 1937, showed no corrosion.

That this unusual type of corrosion may occur in many other high-pressure boilers seems improbable, but because of its severity, operation of new high-pressure boilers might well be predicated on a knowledge of corrosion rates at least before permanent films are established. That manually applied coatings can be effective is not indicated by this experience.

Present Water Conditioning

The following boiler-water analysis has been averaged for several recent months.

	ppm
Pht. Alkalinity, as NaOH	6
Sodium phosphate, as Na_2HPO_4	60
Sodium sulphate	12
Suspended solids	0
Total	78

Blowdown is 36,000 lb per day ($^1/_3$ per cent of output, but probably five times the raw water input); specific resistance of the condensate averages 1,500,000 ohms per cc; and a total of approximately 5 lb of mono-sodium and tri-sodium phosphate are charged daily.

Dissolved gas content of the steam has for several months averaged 0.015 cc per liter of nitrogen and 0.003 cc per liter of hydrogen. The latter represents

TABLE 2

SUMMARY OF OUTPUT AND OUTAGE DATA
November 22, 1935 to December 26, 1937 (2.07 Years)

	Totals	Percents
Hours Elapsed	18,340	100
Plant Operated	15,807	86.2
Plant Outages		
General, scheduled inspections	1,135	6.2
Lack of load	455	2.5
Mechanical trouble	414	2.2
Corrosion trouble	529	2.9
Total	2,533	13.8
Plant Availability		86.7%
Output, KWH		850,759,500
Average load, KW		53,929
Peak load, KW		82,000
Load factor, %		65.8%

the corrosion of 3 ounces of iron per day, and may have its origin in the superheaters because it is not responsive to any boiler-water treatment.

Steam Temperature Control

A total superheated steam temperature of 831 F and 829 F reheat was averaged at the turbine for the year 1937 without ever exceeding 850 F. Again during the Spring months, early-morning loads often were as low as 20,000 kw for many hours, but as previously, examination of typical steam temperature charts showed no indication of the 3 to 1 load changes. For this close steam-temperature regulation to occur inherently in equipment absorbing 45 per cent as much heat in super-heating as in evaporation, makes this result all the more significant. In future plants imparting more superheat than latent heat, equally close regulation will probably be an absolute necessity.

Aside from an initial 12 per cent reduction of reheater surface, the reheat system has continued practically

TABLE 3

MONTHLY OUTPUT AND HEAT CONSUMPTION DATA

Year	Month	Output, KWH Gross	Output, KWH Auxiliary	Output, KWH Net	Heat Consumption, BTU/KWH Gross	Heat Consumption, BTU/KWH Auxiliary	Heat Consumption, BTU/KWH Net
1935	October	3,353,000	431,600	2,921,400	14,215	2,100	16,365
	November	3,961,000	359,700	3,601,300	12,159	1,214	13,373
	December	33,853,000	1,969,000	31,884,000	10,962	677	11,639
	3 Months	41,167,000	2,760,300	38,406,700	11,342	815	12,157
1936	January	36,302,000	1,969,000	34,332,071	10,721	615	11,336
	February	35,938,000	1,914,502	34,023,498	10,655	600	11,255
	March	24,879,000	1,390,674	23,488,326	10,804	640	11,444
	April	32,333,000	1,795,342	30,537,658	10,339	607	10,946
	May	28,031,000	1,570,718	26,460,282	10,411	618	11,029
	June	28,033,000	1,513,510	26,519,490	10,373	592	10,965
	July	37,670,000	1,911,608	35,758,392	10,328	552	10,880
	August	41,189,000	2,061,043	39,127,957	10,314	543	10,857
	September	39,980,000	2,000,309	37,979,691	10,218	538	10,756
	October	29,326,000	1,524,682	27,801,318	10,135	556	10,691
	November	35,395,000	1,816,006	33,578,994	10,047	543	10,590
	December	35,089,000	1,833,459	33,255,541	10,282	567	10,849
	12 Months	404,165,000	21,301,782	382,863,218	10,376	578	10,954
1937	January	18,859,000	1,125,827	17,733,173	10,678	678	11,356
	February	37,489,000	1,926,968	35,562,032	10,398	563	10,961
	March	23,802,000	1,281,259	22,520,741	10,414	593	11,007
	April	26,580,000	1,442,464	25,137,536	10,353	594	10,947
	May	33,274,000	1,731,669	31,542,331	10,230	561	10,791
	June	35,166,000	1,770,473	33,395,527	10,132	537	10,669
	July	41,961,000	2,062,370	39,898,630	10,235	530	10,765
	August	42,988,000	2,099,808	40,888,192	10,275	528	10,803
	September	40,862,000	2,050,057	38,811,943	10,206	539	10,745
	October	28,122,000	1,515,084	26,606,916	10,292	586	10,878
	November	38,919,000	1,967,740	36,951,260	10,163	542	10,705
	December	40,973,000	2,106,791	38,866,209	10,225	554	10,779
	12 Months	408,995,000	21,080,510	387,914,490	10,277	558	10,835
1936-7	24 Months	813,160,000	42,382,292	770,777,708	10,326	568	10,894
1935-7	27 Months	854,327,000	45,142,592	809,184,408	10,375	579	10,954

trouble-free. It has not complicated operation, nor has it been the direct, or indirect, cause of any outage. A few "weeps" in the reheater elements have been welded when found upon inspection. The economy value of reheat is especially important when extremely low exhaust pressures occur in a high-pressure plant, as in this one.

Steam Turbine

Reference to Table 5, items 58 to 60, will show high turbine efficiencies sustained during the second year. was relieved, which stopped leaks observed temporarily after full load was assumed, and two sections of the shroud were replaced.

During the thirteen-day outage in January to replace water-screen tubes, four rows of blading in the low-pressure section were replaced with assemblies of later design. Cracks in blades near the end of some blade sections had been observed on inspection. The new sections were shorter in order to reduce fabrication stresses. The stellite-shielded exhaust blades continue to show practically no erosion, despite the low exhaust

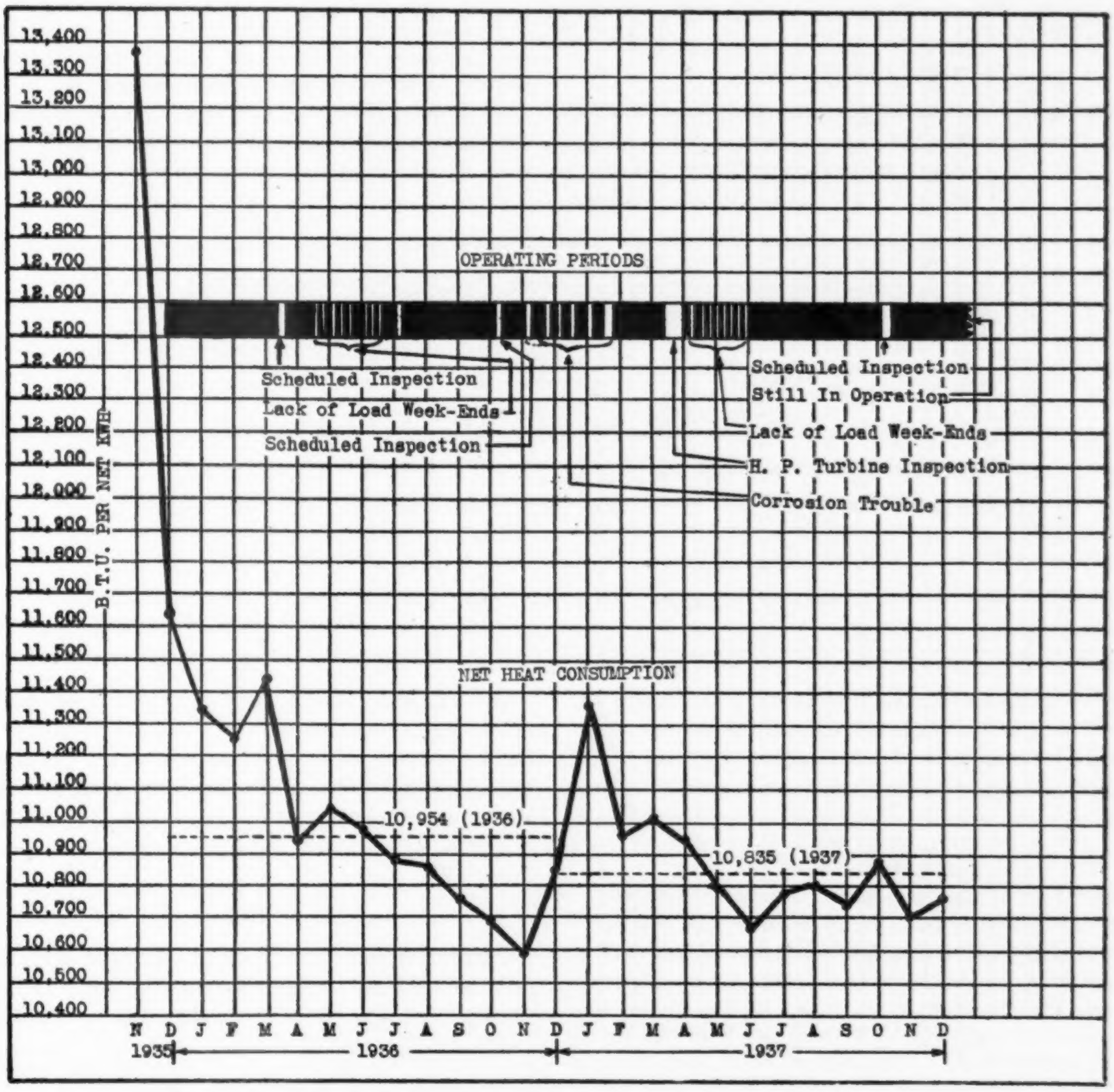

Fig. 3—Operating periods and monthly heat consumption for 1936 and 1937

10,835 Btu per net kilowatt-hour average during 1937 is a fair gage of the station's inherent economy. The lowest monthly net heat consumption has been 10,590 Btu per net kilowatt-hour. Each spring seven week-end outages occur due to hydro-electric supply causing lack of station load. Port Washington is not a base-load plant; hence its average annual load factor is 58 per cent.

Internal inspection of the high-pressure section in March 1937, after 10,000 hr operation, disclosed no evidence of rubbing of any of the low-clearance parts in the high-pressure blades and dummies. This experience seems all the more unusual when the large total axial expansion of 0.9 in. (from cold to full load) is contemplated and compared with minimum operating clearances of a low order. During this internal inspection, the horizontal joint near the bore of the cylinder pressures employed. The vibration amplitude on all bearing covers is less than 0.001 in.

Turbine heating practice when starting consists of normally regulating the total axial expansion to a uniform rate of 0.06 in. per hr, although if necessary 0.12 in. per hr can be used in emergencies. A uniform expansion rate necessitates low-load operation for several hours after synchronizing, and therefore causes the starting load-time curve to be definitely parabolic

in shape. Steam temperatures are increased at the rate of 100 F per hr. In fact, a 100 F hourly heating rate for most power plant equipment appears a favorable rule to follow.

On the occasion of an operating error in July 1937, when the generator switch was opened at 60,000 kw load, the turbine speed increased to a maximum of 1970 rpm, (10 per cent overspeed), thus affording an inadvertent test of the effectiveness of the reheater-system intercepting valves. They have since been adjusted to hold the turbine below tripping speed, thus permitting its automatic resumption of load.

Availability data of the turbine, boiler and plant are given in Table 4.

Condenser Performance

An average 1937 exhaust pressure of 0.49 in. and an average turbine correction rate of over 1 per cent per 0.1 in. change in exhaust pressure, emphasize the value of excellent condenser performance upon this stations' economy. Tests show that the turbine at 60,000 kw load continues to utilize lower exhaust pressures at the above high rate down to at least 0.3 in. absolute. Several 0.25-in. absolute exhaust pressures, determined accurately, are on the 1937 records. Average exhaust pressure for a recent month, with 57,000 kw average load and 35 F circulating water, was 0.31 in.

Refrigeration of the condensate is usually "negative," and for most of the year the condensate is positively free of oxygen. For a long period, 0.005 cc per liter of oxygen in the boiler feedwater, checked by accurate volumetric measurement of nitrogen in the steam, was completely accounted for by 0.15 cc per liter oxygen in the No. 1 heater drain. This admits of no oxygen from the condenser hotwell.

Vibration of three tubes in a high velocity zone within the condenser tube bank caused a Thursday night outage on one occasion due to the complete fracture of one tube. All similarly located tubes have since been stayed. The tubes are still extremely smooth inside and free of any deposits other than a slight stain.

Feedwater Regulation

Push-button control of the regulating valves by the boiler operator, assisted by a water-flow, steam-flow meter on which the recording pens are kept together, continues very satisfactory. There have been no cases of high or low water. The water level recorder seldom shows more than 1 in. departure from the drum centerline.

Additional periscopes have been installed so that the operator can see three water glasses from his control position, plus the recorded level. Sodium phosphate charges of more than 5 lb cause a noticeable increase in rear drum levels. When this was first observed, the superheat temperature dropped 25 deg as the rear drum level rose 8 in. Phenolphthalein alkalinity was 200 ppm and the phosphate content 100 ppm at the time.

Extraction Heaters

Rolled joints of the thick steel tubes in the heavy tube sheets of the three sets of high-pressure heaters still require occasional minor maintenance due to leakage. The projecting end of the leaking tube is removed by machining and then a seal weld is applied. No tubes that were corrected in this manner have subsequently leaked.

Heat transfer of the heaters is now practically coincident with guarantees. To prevent reduced transfer due to rusting, the tubes are dried by circulating air through the heaters after shutdown until all are dried. Reduction of heater-drain flash losses by sub-cooling with the lower tubes submerged has been completely successful.

Piping

Current trouble with piping has been confined to a gasketed, deeply serrated joint between the turbine strainer and the throttle valve. The original copper-nickel gasket was replaced with a soft iron gasket in June 1937. Because the bolts had already experienced their initial creep and because the creep properties of iron are much better than those of copper-nickel at 825 F, the bolts were not "followed-up" during the recent October outage. A small leak occurred late in November, and will probably be permitted to continue until the contemplated Spring inspection outage in March or April.

Two Sarlun flanged joints on 825 F service were inspected in October 1936, to learn how much of the original 50,000-lb per sq in. stress still occurred in the bolts. Measurements indicated that rapid initial creep had reduced the stress to 15,000 lb per sq in. Theory indicates that this latter value of stress will reduce very slowly.

TABLE 4

USE AND AVAILABILITY DATA

Year	1936			1937			1936-7 Average		
Equipment	Boiler	Turbine	Plant	Boiler	Turbine	Plant	Boiler	Turbine	Plant
Annual Use Factor $\left(\frac{\text{Service Hours}}{\text{Annual Hours}}\right)$	86.2	85.8	85.8	84.4	84.3	84.3	85.4	85.0	85.0
Hourly Output-Capacity Factor $\left(\frac{\text{Ave. hourly output}}{\text{Rated hourly output}}\right)$	60.2	66.4	66.4	61.9	69.2	69.2	61.0	67.8	67.8
Annual Output-Capacity Factor $\left(\frac{\text{Annual Output}}{\text{Annual Rated Output}}\right)$	51.9	57.2	57.2	52.2	58.4	58.4	52.0	57.8	57.8
Annual Demand Factor $\left(\frac{\text{Demand hours}}{\text{Annual hours}}\right)$	95.8	96.8	96.8	91.3	93.7	97.1	93.5	95.2	96.9
Demand Availability Factor $\left(\frac{\text{Service hours}}{\text{Demand hours}}\right)$	89.9	88.9	88.9	92.4	90.0	86.8	91.2	89.4	87.8
Annual Availability Factor $\left(100-\frac{\text{Repair hours}}{\text{Annual hours}}\right)$	91.1	98.1.	89.8	93.1	89.9	86.5	92.1	93.1	88.2

TABLE 5 -- AVERAGES OF DAILY OPERATING DATA

DATE, Month Ending	Jan. 26	Feb. 24	March 26	April 25	May 26	June 25	July 26	Aug. 26	Sept. 25	Oct. 26	Nov. 25	Dec. 26	Annual Ave. 1937	Annual Ave. 1936
COAL, TONS PER DAY														
1. To bunker	490	540	483	520	494	539	538	541	530	467	486	529	513	495
2. Pulverized	480	539	518	494	496	536	533	543	528	492	500	517	515	495
3. Burned, approx.	481	538	530	484	495	537	536	545	526	491	500	517	515	496
4. Mill hours	35.45	36.72	31.11	30.04	30.63	33.27	30.59	31.35	34.97	32.94	28.79	31.43	32.89	33.79
5. Mill tons per hour	13.5	14.7	16.7	16.4	16.2	16.2	17.4	17.2	15.1	15.0	17.5	16.4	16.0	14.7
6. Mill system KWH per ton	16.6	14.1	14.8	13.2	13.8	13.9	13.7	14.0	16.0	16.5	13.3	13.8	14.6	15.8
7. Moisture, mill in, %	3.9	4.2	3.7	3.9	4.3	4.6	3.7	3.0	3.5	3.0	3.3	3.6	3.7	3.6
8. Moisture, mill out, %	1.8	1.8	1.7	1.7	1.9	1.9	1.7	1.5	1.5	1.5	1.5	1.6	1.7	1.8
9. No. 1 Mill Fineness % through														
200 mesh	75.95	73.15	63.32	63.86	62.96	62.71	63.10	61.21	64.57	65.41	64.25	62.97	65.28	65.14
100 mesh	94.83	92.97	87.47	88.69	88.10	87.44	86.79	85.64	87.58	89.01	88.55	88.35	88.78	89.21
48 mesh	99.57	98.98	97.15	97.97	97.78	97.49	97.21	96.69	97.60	98.10	97.94	97.92	97.86	97.97
28 mesh	99.95	99.88	99.82	99.77	99.74	99.72	99.62	99.60	99.73	99.84	99.80	99.78	99.74	99.76
20 mesh	99.98	99.96	99.91	99.96	99.97	99.97	99.95	99.95	99.97	99.98	99.98	99.97	99.96	99.98
10 mesh	100	100	99.99	100	100	100	99.99	100	100	100	100	100	99.99	99.99
10. No. 2 Mill Fineness % through														
200 mesh	66.28	64.75	64.88	63.75	63.39	63.97	66.35	66.34	66.94	67.31	65.49	62.95	65.06	66.55
100 mesh	89.31	87.98	88.11	88.22	88.46	88.61	89.42	89.15	89.68	89.67	87.94	86.54	88.58	90.15
48 mesh	98.22	97.68	97.65	97.53	97.90	97.84	98.03	97.87	98.18	98.18	97.45	97.01	97.78	98.39
28 mesh	99.83	99.75	99.71	99.84	99.76	99.78	99.78	99.74	99.82	99.80	99.67	99.57	99.73	99.81
20 mesh	99.98	99.96	99.97	99.95	99.97	99.97	99.97	99.96	99.98	99.98	99.97	99.95	99.96	99.97
10 mesh	100	100	100	99.99	100	100	100	100	100	100	100	100	99.99	99.99
11. Btu/lb, ash, moisture free	15167	15035	14860	14833	14820	14783	14900	14910	15032	15114	15078	15068	14967	14939
12. Btu/lb, dry	13609	13551	13405	13448	13360	13381	13543	13495	13769	13779	13659	13646	13552	13606
13. Btu/lb, as received	12971	12920	12868	12894	12731	12709	13000	13031	13204	13311	13115	13046	12983	13035
14. Moisture, %	4.7	4.7	4.0	4.1	4.7	4.8	4.0	3.4	4.1	3.4	4.0	4.4	4.2	4.3
15. Volatile, %	34.18	33.80	33.89	34.55	34.80	34.77	36.44	35.69	35.28	35.47	34.30	34.71	34.82	35.87
16. Fixed carbon, %	55.55	56.33	56.32	56.11	55.35	55.55	54.45	54.82	56.32	55.70	56.29	55.85	55.72	55.21
17. Ash, %	10.27	9.87	9.79	9.34	9.85	9.68	9.11	9.49	8.40	8.83	9.41	9.44	9.46	8.92
18. Sulphur, %	2.07	1.96	2.03	1.98	1.88	2.37	2.22	2.22	1.52	1.70	1.48	1.54	1.98	2.51
19. Ash fusion temperature, °F	2273	2265	2255	2261	2263	2230	2186	2204	2207	2235	2255	2254	2241	2199
20. Pulverized Coal Composite Sample														
Btu/lb, ash, moisture free	15128	15036	14809	14815	14787	14788	14831	14880	15068	15068	15041	15051	14943	14968
Btu/lb, dry	13677	13536	13294	13382	13279	13338	13415	13463	13727	13721	13685	13596	13508	13623
Btu/lb, as received	13515	13315	13097	13164	13061	13096	13212	13254	13507	13515	13430	13392	13299	13414
Moisture, %	1.2	1.6	1.5	1.6	1.6	1.8	1.5	1.6	1.6	1.5	1.5	1.5	1.5	1.6
Volatile, %	34.99	32.99	32.78	33.71	33.79	34.97	35.91	35.43	34.87	35.28	34.18	34.19	34.43	35.80
Fixed carbon, %	55.42	57.02	56.99	56.62	56.01	55.22	54.54	55.05	56.23	55.78	56.47	56.14	55.93	55.23
Ash, %	9.59	9.99	10.23	9.67	10.20	9.81	9.55	9.52	8.90	8.94	9.35	9.67	9.62	8.97
Sulphur, %	1.90	1.88	1.96	1.91	1.94	2.17	2.31	2.22	1.53	1.72	1.33	1.46	1.88	2.51
BOILER ROOM														
21. Steam, million lb/day	8.921	10.004	9.946	9.273	9.251	10.066	10.225	10.598	10.592	9.901	10.072	10.238	9.924	9.733
22. Feedwater, mil. lb/day	8.804	10.035	9.899	9.243	9.240	10.064	10.144	10.449	10.302	9.668	9.794	9.960	9.801	9.556
23. Ave. output, thd. lb/hour	406	417	414	410	401	424	426	442	441	413	420	427	420	412
24. Hours steaming per day	21.97	24.00	24.00	22.62	23.08	23.70	24.00	24.00	24.00	24.00	24.00	24.00	23.62	23.65
25. Hours banked per day	0.16	0	0	0.45	0.92	0.30	0	0	0	0	0	0	0.16	0.22
26. % excess air	32	25	25	34	25	21	19	17	17	22	18	19	23	20
27. Pressure. lb. Gage	1158	1156	1181	1151	1196	1218	1211	1206	1209	1168	1205	1216	1190	1221
28. Feedwater Temperature, °F	368	351	356	380	366	375	371	384	398	392	395	394	378	381
29. Feedwater pressure, lb. Gage	1390	1417	1406	1420	1402	1383	1338	1291	1307	1358	1326	1379	1368	1421
30. B. F. pump efficiency % actual	64.2	67.1	66.8	63.7	65.7	66.4	66.3	67.3	67.2	66.9	65.3	64.1	65.9	65.4
31. B. F. pump efficiency % stand.	65.6	65.0	65.2	66.5	65.8	64.4	64.3	62.8	63.0	65.2	64.8	65.5	64.9	65.1
32. % combustible in fly ash	11.08	11.43	11.24	11.79	11.56	10.21	14.57	13.05	15.21	11.74	12.51	10.69	12.09	13.48
33. Exh. to htrs. thd. lb/day	5.5	0.8	0.9	9.5	6.9	3.2	0.7	0	0	5.1	0.1	0	2.6	15.2
Steam Temperature, Deg. F.														
34. Radiant superheater out	671	670	664	674	673	672	669	670	674	674	679	680	673	675
35. Convection Suphtr. out	837	840	840	832	836	836	838	841	841	841	843	842	839	831
36. Reheater in	542	545	543	536	534	536	539	542	540	535	536	537	538	534
37. Reheater out	834	839	841	830	838	840	842	844	842	841	843	843	840	831
Gas Temperatures, Deg. F.														
38. Air heater in	743	743	746	720	727	741	748	751	749	743	740	732	741	734
39. Air heater out	366	370	371	353	362	376	392	400	398	376	371	367	375	378
40. Drop	377	373	375	367	365	365	356	351	351	367	369	365	366	356
Air Temperatures, Deg. F.														
41. Air heater in	166	165	163	163	164	163	165	181	181	180	179	174	171	159
42. Air heater out	564	567	569	557	542	545	545	536	530	545	564	552	551	549
43. Forced draft fan in	109	110	111	112	115	120	126	127	126	130	117	115	118	115
44. Rise	455	457	458	445	426	425	419	409	404	425	437	439	433	434
45. % air through heater	93	92	92	93	96	96	96	96	98	97	95	94	95	92
46. Htr. Performance, % of std.	108	106	106	113	103	97	90	88	87	102	106	106	101	97
TURBINE ROOM														
47. Average load, KW	53604	55333	54699	52176	53284	56176	56206	57730	56819	53342	54137	55199	54665	52771
Temperatures, Deg. F.														
48. Throttle	830	832	831	823	829	830	830	834	835	831	834	834	831	825
49. 1st inlet	820	824	822	807	812	816	818	825	825	819	820	822	820	809
50. Reheater in	549	551	549	541	540	542	545	548	545	540	540	540	544	541
51. Reheater out	825	830	828	818	825	828	829	831	830	830	832	832	829	822
52. No. 3 heater	493	501	504	489	499	501	502	505	502	497	499	501	500	488
Pressures, lb. Gage														
53. Throttle	1134	1135	1159	1130	1176	1197	1186	1182	1183	1145	1179	1186	1166	1184
54. 1st inlet	1030	1046	1052	956	992	1042	1047	1091	1088	1008	1022	1046	1035	986
55. Reheater in	266	273	271	257	263	276	278	286	281	259	262	267	270	258
56. Reheater out	235	241	239	226	232	243	245	253	249	229	231	236	239	229
57. No. 3 heater	35.8	37.2	37.0	35.3	36.9	39.2	39.4	40.8	39.7	35.6	36.2	37.2	37.6	34.5
Stage Efficiencies, %														
58. 1st in to reheater in	78.0	79.0	77.9	80.1	80.8	80.9	80.5	80.6	81.0	80.8	80.9	81.1	80.2	77.9
59. Reheater out to No. 3 heater	84.5	83.5	82.3	84.9	84.3	84.3	84.2	83.7	83.9	85.1	85.5	85.2	84.3	85.4
60. Both	81.6	81.5	80.3	82.8	82.8	82.8	82.6	82.4	82.6	83.3	83.5	83.3	82.5	82.1
61. Cir. water out, °F	40.7	39.8	38.3	42.9	49.7	53.3	61.6	67.6	65.5	53.2	45.8	39.1	49.8	50.8
62. Cir. water in, °F	36.2	35.5	34.1	39.0	45.7	49.1	57.6	63.6	61.6	49.3	41.7	34.9	45.7	46.7
63. Cir. water rise, °F	4.5	4.3	4.2	4.0	4.0	4.2	4.0	4.0	3.9	3.9	4.1	4.2	4.1	4.1
64. Condensate, °F	49.5	47.5	45.5	51.1	57.5	60.9	68.7	74.4	72.4	60.4	53.7	47.7	57.5	58.5
Exh. Pressure, in. Hg. Abs.														
65. Actual	.36	.33	.32	.37	.45	.52	.68	.82	.77	.50	.39	.31	.49	.56
66. Standard	.36	.36	.34	.40	.47	.52	.68	.83	.76	.52	.43	.35	.51	.51
67. High(+) or low(-)	0	-.03	-.02	-.03	-.02	0	0	+.01	+.01	-.02	-.04	-.04	-.02	*.05
68. Air pump inlet	.36	.33	.30	.34	.41	.47	.63	.77	.74	.46	.36	.27	.46	.54
69. Air leakage, CFM	4.3	3.4	3.0	4.6	4.2	4.0	3.5	3.3	3.5	3.6	3.0	2.8	3.6	3.1
ELECTRICAL														
70. Output, gross, 1000 KWH/day	1178.8	1338.7	1321.7	1208.2	1232.3	1343.0	1353.6	1386.7	1362.1	1278.3	1297.3	1321.7	1301.9	1256.2
71. Output, net, 1000 KWH/day	1114.0	1269.9	1254.5	1144.6	1169.0	1275.8	1287.1	1319.0	1293.7	1211.8	1231.7	1253.7	1235.4	1190.8
72. Auxiliaries, 1000 KWH/day	64.8	68.8	67.2	63.6	63.3	67.2	66.5	67.7	68.4	66.5	65.6	68.0	66.5	65.4
73. Auxiliaries. %	5.5	5.1	5.1	5.3	5.1	5.0	4.9	4.9	5.0	5.2	5.1	5.1	5.1	5.2
74. % for coal preparation	.68	.65	.58	.56	.55	.55	.54	.54	.62	.64	.51	.54	.58	.62
75. % for boiler room fans	1.17	1.04	1.05	1.07	1.02	1.04	1.03	1.06	1.04	1.05	1.03	1.03	1.06	.98
76. % for boiler feed pumps	1.56	1.49	1.49	1.60	1.49	1.45	1.42	1.37	1.42	1.46	1.48	1.56	1.48	1.57
77. % for circ. pumps	1.16	1.07	1.08	1.19	1.11	1.05	1.05	1.03	1.05	1.12	1.11	1.09	1.09	1.13
78. % for miscellaneous	.93	.85	.90	.88	.93	.91	.86	.90	.87	.93	.97	.86	.89	.90
Station Heat Consumption BTU per KWH														
Gross	10678	10398	10414	10353	10230	10132	10235	10275	10206	10292	10163	10225	10277	10376
Auxiliaries	678	563	593	594	561	537	530	528	539	586	542	554	558	578
Net	11356	10961	11007	10947	10791	10669	10765	10803	10745	10878	10705	10779	10835	10954

The air heater has not been entirely free of accumulations as the "Heater Performance, Per Cent of Standard," item No. 46 of Table 5 shows. Since the October 1937 outage, when the heater was thoroughly soaked and washed with liberal quantities of water to make it scrupulously clean, its performance has stayed well above the specified heat transfer rate, used as "Standard Performance." In the plate-type of heater, clogging is undoubtedly accumulative (to a certain point) and its correction therefore necessitates perfect initial cleaning of its surfaces.

TABLE 6

ANALYSES OF INTERNAL TUBE COATINGS

Showing Character of Films Protective Against Corrosion

Coating	Straw-Color	Gray	Dark
Location in tube cross-section	Top 3/8"	Adjacent 1/8" Both Sides	Remainder Sides & Bottom
Analyses			
Phosphate	2.9	32.1	21.4
Iron, %	86.0	52.2	55.8
Total, %	88.9	84.3	77.2
Calculated As			
Iron Phosphate, %		51	34
Magnetic Iron Oxide		46	60
Total, %		97	94

The boiler feed pumps have had essentially 100 per cent availability, for the only work done upon them in the two years consisted of stopping bearing-oil contamination of the motor windings. Though their efficiency is still above the specified value, they have lost about 3 per cent in capacity. One of the two motor-driven pumps is used for the usual station load of 60,000 kw, now decreased to 58,000 kw due to the 3 per cent drop in pump capacity. Their efficiency is reported in Table 5, item 30.

The pulverized-coal bin, ventilated with warm flue-gas, has not been cleaned since new and apparently will not require cleaning in the near future. Keeping the top of the bin dry with flue-gas not only eliminates cleaning and bin corrosion, but is good insurance against bin fires and feeder troubles, none of which have been experienced.

Conclusions

Study of significant experiences, all of which are reported herein, indicates that the plant continues to be "reliable, easily operated, and economical" and that, there is no doubt that it represents an improvement (over Lakeside) in all respects.[2] The corrosion experience illustrates the character of the new frontiers which pioneering plants face. The excellence of most of the equipment in the plant shows the present-day high standards of mechanical construction now available for steam power development which makes the single-boiler, single-turbine arrangement both practicable and reliable.

[2] See *Mechanical Engineering*, November 1936.

The Engineer's Societies

Engineering as a profession is comparatively young although the practice of engineering is old. Compared with the medical and legal professions, it is poorly organized. There are at least a hundred different technical societies in the United States, but only one professional engineering society. A unified profession should be the goal of every engineer and eventually there will be a demand for a single association, covering both professional and technical needs, similar to the American Medical Association and the American Bar Association. Perhaps it will be named the "American Engineering Association." In the words of Kipling:

> "It aren't guns nor armaments
> nor funds that we can pay,
> But's the close cooperation
> that makes us win the day.
> It's not the individual
> nor the army as a whole,
> But the everlasting team-work
> of every bloomin' soul."

At present each of the societies effectively serves the technical requirements of its own field, but cannot serve the broader engineering interests of its members as well as could a single coordinated society composed of all the present societies, each carrying on the work in its particular field without duplicating that of the others Thus the broader professional interests would be centralized without affecting the specialized technical activities. The component groups of such a society might be compared to the departments of a corporation, each essentially a small company in itself, but unless the work of each department is coordinated as a part of the activities of the corporation, the business will not function efficiently.

The advantages of consolidation may be illustrated by the Engineering Societies' Library which is composed of the libraries of several technical societies. While each lost its individual library, the combined library has gained in size, importance and ability to serve.

It may be well to point out here that the engineering profession should not affiliate with unions. The engineer's work is largely creative and he should have a free hand. Many engineers, in a sense, belong to the employer class in that they must of necessity direct labor. Hence, they must be free to view the problems of production from the economic and labor-saving standpoints.

The trend among our leading technical schools is away from specialization and toward preparing the graduate, by broad training, to enter such branches of engineering as opportunity may offer.

It is fitting that engineers be among the leaders in industry and, as such, they must possess broad engineering viewpoints. The chief engineer of today is seldom a true specialist in that he is concerned with one branch of engineering only. Although he may depend upon assistants for detailed information in other lines, he, himself, must have a general understanding of allied fields. Therefore, just as he coordinates work dealing with several fields, so will he be likely to welcome a single society constituted along the lines suggested.

To illustrate this further, one might consider the average corporation in which a vice president is in charge of each major division of the business. When the time comes for a new president to be chosen from among the vice presidents, length of service or the relative importance of the particular department are usually subordinate to the capacity of the individual to view the problems of the organization from all angles and to guide its activities toward a unified and successful goal.

In order to protect the public, only qualified engineers should be permitted to practice engineering. In many states this is prescribed by law through licensing and professional registration, based upon examination and experience. An investment of much time and money is represented in the training and experience of such engineers, and the professional engineering society is organized to protect and increase the value of this investment as well as to look after the economic problems and welfare of the profession in its relation to the public.

Undoubtedly, unification of our engineering societies would be a slow process, involving much discussion and time in arriving at a suitable basis. It is believed, however, that the idea is gaining momentum and that it will eventually be brought about.

C. J. NICASTRO

Superheaters for High-Temperature, High-Pressure Service

By FREDERIC I. EPLEY

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Factors influencing the performance of superheaters are discussed, as well as the problems confronting the designer when the steam generating unit is expected to operate on more than one kind of fuel. Methods of superheat control necessary to prevent variations in steam temperature with wide changes in load, and other problems of design, such as draft loss and pressure drop through the superheater, are reviewed.

MUCH of the credit for the increased use of the high-pressure high-temperature steam generating units is due to the development of superheaters of economical design, giving satisfactory performance to suit the needs of present-day practice. Suitable materials, for both the pressure parts and the non-pressure parts, which have been developed to date have given the designer considerably more latitude in the selection of materials and improvements in methods of fabrication have made possible superheater designs that were not altogether practical a few years ago.

Of the several points that must be given consideration in the design of superheaters for high-pressure, high-temperature operation, one of the most important is that of performance. This includes variation in steam temperature, draft loss and pressure drop with changes in capacity of the steam generating unit. Furthermore, the changes in superheater performance must be accurately predicted for any changes in operating conditions that are likely to vary from those expected as normal.

Of the three items noted, the most important and perhaps the most difficult to predict is the steam temperature with changes in steam output and changes in other operating conditions. The importance of predicting the steam temperature within the closest practical limits is due primarily to the fact that this is tied up very closely with the performance of the turbine. Should the steam temperature become too low the efficiency and capacity of the turbine will be impaired, as well as the possibility of excessive condensation in the low-pressure stages. If the steam temperature becomes too high, the turbine as well as the superheater, piping and fittings, may be subjected to damage due to the materials of the various parts not being suitable for the high temperatures encountered.

It is interesting to note that of the many high-pressure, high-temperature installations which have been put into operation within the last few years and those to be put into operation shortly, an impressive majority have been designed with superheaters located in the path of active gas flow and derive practically all of their heat from the convection action of the hot gases. Such steam generating units employ water-cooled furnaces which absorb a large part of the heat liberated. The furnace is usually followed by a small section of boiler heating surface consisting of only a few rows of tubes and the superheater of the convection type is placed just beyond these boiler tubes. In most designs the superheater pass is followed by a second bank of boiler tubes, the principal function of which is to provide a path for water circulation in the boiler and to provide a pass for regulating the gas flow over the superheater for the control of steam temperature. This boiler section is then followed by the economizer and air heater of such proportions as to give the most economical arrangement for the complete unit.

With the advent of these high-pressure high-temperature steam generating units, some operators have resorted to the use of a single boiler unit per turbine which results in operation over a wide range of output in order to satisfy varying demands on the system. Obviously, if the superheater were designed to give the normal operating steam temperature at some lower load such as 50 per cent of maximum capacity, at the higher output the temperature may be entirely too high to permit safe operation of the prime mover and other equipment. Similarly, if the superheater were designed for the desired steam temperature at full load, at lower outputs it would be too low to permit the full economical operation of the prime mover. This characteristic is inherent with the convection superheater. Despite this the steam temperature curve can be made reasonably flat by proper design and proper location of the superheating surface in the path of the gases.

Several years ago, when steam pressures and temperatures were considerably lower than those in use today, control of steam temperature was seldom employed, for its variation with operating conditions was seldom great enough to cause any trouble. However, with present-day boiler units, the variations in steam temperatures may be too great for safe operation, and because of this the control of steam temperatures has become a necessity as well as a desirable feature.

With superheaters of the convection type it is quite necessary that there be available at the inlet a sufficient gas temperature to permit the design of an economical size of superheater. The counterflow principle is frequently utilized, which will account for the minimum amount of superheating surface for given conditions. However, even with a counterflow arrangement a minimum difference between the gas temperature and that of the steam is required for a reasonable design. Thus by fixing the minimum gas temperature entering the superheater at some output such as 50 per cent of full load in order to obtain the steam temperature required, the entering gas temperature at full load can be estimated. By fixing the amount of boiler surface between the superheater and furnace, the maximum gas temperature leaving the furnace is established.

On the other hand, the maximum gas temperature leaving the furnace is frequently fixed either by the operators or by the characteristics of the fuel fired, such as the fusion temperature of the ash. By determining the drop in gas temperature through the boiler tube bank between the furnace and the superheater, the gas temperature entering the superheater can be arrived at for full load. This, in turn, fixes the gas temperature at lower outputs depending upon the expected operating conditions. With the gas temperatures at lower outputs determined, it is possible to arrive at the minimum load at which the full steam temperature can be obtained with the superheating surface that can be installed in the space available. Thus, the superheater designer is limited both by the minimum gas temperature at the lowest output at which the full steam temperature is obtainable and the maximum gas temperature leaving the furnace at full load at which operation of the unit can be maintained without undue slagging in the furnace.

Influence of Dual Firing

A further complication of the problem of the designer occurs when more than one type of fuel is fired in the same unit. For a given design of furnace and boiler, and with the superheater located near the furnace in a high gas temperature zone, the superheater surface will be a maximum when firing oil fuel, although the furnace will be designed to give a maximum gas temperature satisfactory for good operation when being fired with pulverized coal. Likely as not, if the furnace is sufficiently large for good operation with coal, the gas temperatures entering the superheater when burning oil will be too low to obtain the full steam temperature at the lower outputs.

From the foregoing, it can be seen that if a superheater is designed to give the full steam temperature with the more unfavorable conditions such as low gas temperatures and gas weights, that some means must be provided to reduce the steam temperature when operating under more favorable conditions. This can be done in two most usual ways, both of which have been employed on installations that are now in operation: these are, (1) control of gas flow over the superheating surface; and (2) desuperheating the steam either at the superheater outlet or at some intermediate point between two superheaters. Of the two methods, the trend at present is toward the first mentioned method, as the construction and physical requirements for the pressure parts are simplified to the greatest extent. The control of gas flow over the superheater appears at present to afford considerable latitude in the range of control which can be obtained, and can be used in steam generating units designed to fire several different fuels either separately or in combination.

The performance of the superheater in regard to variations in steam temperature against changes in steam output is almost entirely dependent upon the corresponding performance of the furnace, fuel burning equipment and boiler surface ahead of the superheater. With a given amount of heat liberated in the furnace, a certain proportion will be absorbed in the water-cooled surface exposed to radiant heat. This depends upon the type and location of the water-cooled surface, the method of firing, type of fuel burned and the cleanliness of the surfaces, and fixes according to certain physical laws the gas temperature leaving the furnace.

With a gas temperature drop through the boiler bank, which can be determined by other physical laws, the gas temperature entering the superheater can be determined. Thus, it is evident that if the furnace performance is not the same as that expected, the superheater performance is likewise different from that predicted. In steam generating units for pressures of 1400 lb and steam temperatures of around 925 F, which are not unusual at the present time, a change of 100 deg F in the gases leaving the furnace may account for a change in steam temperature of as much as 30 deg F and it is highly conceivable that differences in gas temperatures of 100 deg F will exist in the various designs of furnaces.

The draft loss in the superheater, like the draft loss in an economizer, or air heater, or boiler, is primarily a process of balancing the cost of superheating surface with that of power required for overcoming the resistance. Thus for a given design of boiler unit, the draft loss is a function of the surface, that is, the higher the draft loss the less the amount of surface required for a given amount of superheating to be done. There are, however, practical limits for the superheater draft loss, the same as for other parts of the steam generating unit. The pressure drop is primarily a process of balancing the cost of superheater arrangement against that of power for overcoming the resistance as well as the extra cost in the boiler and economizer for operating at additional pressures.

However, for high steam temperatures a moderately high steam velocity in the superheater tubing is necessary in order to reduce the actual operating tube temperatures to a minimum. For low temperature superheaters of around 500 F steam temperature, there was considerable latitude between expected tubing temperatures and those temperatures which carbon steel tubes would stand successfully. In high temperature superheaters, however, there is no such latitude allowable, as high temperature tubing is selected within closer limits, just the same as other equipment which is subjected to high temperature steam. Definite figures showing the limits as to gas temperatures, draft loss and pressure drops to cover any general design cannot be given inasmuch as each problem has its own special characteristics to be taken into consideration when arriving at a workable and economical design of superheater.

Protection Against Intercrystalline Attack in Aqueous Solution

Abstract of a paper by W. C. Schroeder, A. A. Berk and R. A. O'Brien, presented at the A. S. M. E. Annual Meeting, reporting on the latest investigations conducted at the U. S. Bureau of Mines Eastern Experiment Station to determine the effectiveness of sodium sulphate, sodium phosphate, other inorganic compounds and a number of organic substances in protecting steel against intercrystalline cracking. The temperature at which stress was applied proved an important factor. Certain organic materials, such as concentrated sulphite waste liquor, lignin sulphonate, quebracho and Philippine cutch, in the order named, appeared much more effective than inorganic substances such as sodium sulphate, sodium phosphate and sodium carbonate.

FROM present evidence it appears that intercrystalline cracks in boiler steel are produced by solutions which corrode the grain boundaries while leaving the crystal faces relatively free from attack. Early investigations indicated that failure of this character was caused primarily by the presence of sodium hydroxide in the boiler water and also influenced to some extent by the surface conditions of the steel. Subsequent experiments, conducted by the U. S. Bureau of Mines Experiment Station under a cooperative arrangement with the Joint Research Committee on Boiler Feedwater Studies, showed that at 250 C (482 F) very small quantities of sodium silicate in the sodium hydroxide greatly influenced the cracking.

Following this discovery it was believed for a time that the sodium hydroxide-sodium silicate solution offered the explanation of intercrystalline cracking, but the latest investigations at the Experiment Station have shown that such cracking can be produced in sodium hydroxide solutions containing a number of substances other than silicate; also that sodium nitrate or dilute nitric acid solutions will behave similar to sodium hydroxide. Furthermore, it has been found that temperature has a marked effect in that certain solutions while not producing cracking at 212 F will do so at 482 F, whereas the presence of certain substances will reverse the process.

The action of various compounds in inhibiting intercrystalline cracking has been studied further at the Bureau of Mines Experiment Station at the University of Maryland and was reported in a paper[1] by W. C. Schroeder,[2] A. A. Berk[3] and R. A. O'Brien[4] at the recent Annual Meeting of the A. S. M. E. The following is abstracted from this paper:

Protection by Sodium Sulphate

Study of the protection that may be afforded by sodium sulphate is extremely interesting in view of its recommended use to prevent cracking in actual boiler operation. It has apparently been satisfactory in many cases but some practical evidence has been offered to show that this is not always true. Its influence in the tension tests has been found to depend upon the temperature at which the stress is applied, and in the U-bend tests on the solution conditions that are producing cracking. The tests were divided into three groups, namely, (1) stress application at room temperature, (2) stress application at 250 C and (3) U-bend tests.

The action of dissolved and solid sodium sulphate, when the stress was applied to the specimen at room temperature and then heated to test temperature, showed, with one exception, no increase in breaking time for concentrations of sodium sulphate up to 12 g per 100 g of water. At 16 g the first specimen failed but the next six did not. This indicated that 16 g of sodium sulphate offers a definite amount of protection, but the last two tests of this series showed that an increase in the silica concentration destroyed this beneficial action. All these tests were run with 25 g of sodium hydroxide per 100 g of water. It was therefore concluded that a solution essentially saturated with sodium sulphate will protect the steel when stress is applied at room temperature or, as suggested by Straub, the presence of solid sulphate exerts a beneficial influence.

In boiler operation it is possible that a butt strap, plate or rivet may suffer distortion or increase in applied stress at operating temperature while in contact with a concentrated solution that will produce intercrystalline cracking. These changes in the metal may be created by temperature or pressure variation, or by vibration or structural movement. It was therefore desirable to determine whether the agents used to prevent cracking would be effective under these conditions. This was done experimentally by applying the stress while the specimen was in contact with the solution at test temperature. Therefore six tests were made in the regular tension bomb on eccentric-grooved specimens with the stress applied at 250 C. Failure quickly occurred in all cases.

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[1] Published by permission of the Director, U. S. Bureau of Mines.
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This same series of tests was repeated on concentric-ground specimens at 250 C and sodium sulphate did not stop failure with sodium-silicate concentrations above 0.8 g per 100 g of water. There is no evidence that sodium sulphate in solution or as loose crystals offers significant protection when the stress is applied at this test temperature.

U-Bend Tests

It has recently been found that boiling sodium hydroxide solutions, in the presence of small amounts of various oxygen-containing compounds, will cause rapid cracking of U-bend specimens. The depth of cracking in a given time, as well as the number of cracks in a specimen, depend on the particular oxidizing agent in solution. For example, sodium hydroxide-sodium chromate solutions will produce relatively fine cracks in 6 or 7 days while sodium hydroxide-lead oxide solutions will crack a $^1/_4$-in. steel specimen almost through in 1 to 3 days. The action of these solutions offers an excellent opportunity to study the protective effect of sodium sulphate under conditions that produce either light or relatively severe cracking.

In sodium hydroxide-sodium chromate solutions, 7 g of dissolved sodium sulphate per 100 g will prevent cracking. On the other hand, covering the specimen with sodium sulphate in sodium hydroxide-lead oxide solutions did not even materially delay cracking. Since the stress on these specimens was unchanged after they were once immersed in the solution, this offers a clear-cut case of almost complete breakdown in protection by dissolved sodium sulphate, or by loose crystals of solid sodium sulphate.

Protection by Sodium Phosphate and Other Inorganic Salts

In the salines of a steam boiler using considerable amounts of treated water for feed, there are appreciable concentrations of a number of inorganic salts other than sodium sulphate. These compounds may include sodium chloride, sodium carbonate, sodium phosphate, sodium sulphite and calcium or magnesium salts. Sodium chloride in certain relatively low concentrations has been found to increase slightly the intercrystalline attack by sodium hydroxide-sodium silicate solutions. The data show that some of the other salts exert a definite tendency to stop the reactions under certain limited conditions.

When the stress was applied at 250 C, 5 g of sodium phosphate stopped failure with only 0.16 g of sodium silicate per 100 g of water. The last two tests in this series show that either the addition of sodium chloride, or increase in silica, destroyed the beneficial action of the phosphate. This salt appears to be definitely inferior to sodium sulphate since it will not stop failure with appreciable silica concentration even when the stress is applied at room temperature.

Sodium sulphate and sodium phosphate in solution together are no more effective than the individual salts in preventing failure of eccentric-grooved specimens. With the stress applied at room temperature, failure occurred in the presence of high silica. When the stress was applied at 250 C, failure occurred in every case. The solutions containing 30 g of sodium sulphate and 3 g of sodium phosphate are approximately saturated at this temperature.

A series of tests were made with sodium carbonate on eccentric-grooved specimens. These are mainly of academic interest, since it is difficult to hold, in a boiler, carbonate concentrations equal to 30 or 40 per cent of the sodium hydroxide. With application of stress either at room- or at high temperature, the addition of enough carbonate would stop failure when the silica was low. A higher concentration of silica destroyed this protection even when the specimen was stressed at room temperature.

Explanation of Temperature Effect

At the present time it is possible to offer only a partial mechanical explanation for the difference produced by stress application at room temperature and at test temperature on the protective action of such salts as sodium sulphate. Stressing the steel at room temperature may produce the major part of the metal distortion so that the sodium sulphate can form a protective film as the bomb heats up that will endure through the test. On the other hand, if the steel is stressed after arrival at elevated temperature, the deformation of the metal may break any film that has been formed at lower temperature, and this film may not reform with sufficient speed to prevent the solution from starting cracks and producing failure. This reasoning assumes that sodium sulphate stops failure through film formation or by reducing the permeability of the iron-oxide layer, and that the reactions that produce the protective coating are slow enough at the elevated temperature to allow intercrystalline attack to occur. These assumptions have not yet been verified by test.

A number of experiments have been run to determine if salts other than sodium sulphate, sodium phosphate and sodium carbonate would stop failure of eccentric-grooved specimens at 250 C. The test solution contained 25 g of sodium hydroxide and from 0.16 to 0.8 g of sodium silicate per 100 g of water, and the stress was applied at room temperature. Failure was not delayed or prevented in the presence of 0.16 g of sodium silicate by potassium iodide, zinc chloride, stannic chloride, sodium aluminate or titanium oxide. High concentrations of sodium fluoride, sodium sulphide, sodium sulphite and sodium arsenite prevented failure only when the sodium silicate concentration was below 0.8 g per 100 g of water.

With the stress applied at 250 C, sodium sulphite, sodium sulphide, sodium arsenite, sodium borate, ammonium chloride, sodium molybdate and iron filings did not stop failure of the steel with sodium silicate concentrations of 0.16 g per 100 g of water. Zirconium chloride stopped failure under these conditions, but this salt probably could not be used in boiler-water treatment. Ferrous sulphate delayed but did not completely stop failure under these conditions.

The test results indicate that failure can be prevented at 250 C by oxidizing agents such as sodium chromate, sodium nitrate and potassium permanganate even when the load is applied at test temperature. These compounds cannot now be suggested for introduction into the boiler due to their possible decomposition and their actual promotion of intercrystalline cracking under some conditions at low temperature.[5]

[5] See "Intercrystalline Cracking of Steel in Aqueous Solutions," by W. C. Schroeder, A. A. Berk and R. A. O'Brien, *Metals and Alloys*, vol. 8, no. 11, pp. 320–330, November 1937.

Protection by Organic Compounds

With the exception of oxidizing agents, no inorganic salt has been found that protects the steel when it suffers material change in stress at elevated temperature in contact with a concentrated sodium hydroxide solution containing appreciable amounts of sodium silicate. In order to secure the maximum protection, chemical methods should be available for stopping failure under the most severe experimental conditions that can be created. Since inorganic salts were not suitable, a large number of tests with organic compounds have been tried.

Using eccentric-grooved specimens under a stress of 40,000 lb per sq in. applied at 250 C, and in contact with a solution containing 25 g of sodium hydroxide and 0.16 g of sodium silicate, the following organic materials did not prevent failure: Soluble starch, stearic acid, tannic acid, gelatine, sucrose, oleic acid, amino stearin, formic acid, gum tragacanth, cellulose and dextine. These compounds have been named in the form in which they were added and not as they existed in the solution. The concentration of each organic material was approximately 1 g per 100 g of water.

The organic material that first protected the steel with the stress applied at high temperature was a residue obtained by evaporation to dryness of the sulphite liquor used to digest wood in the manufacture of paper, which is sometimes denoted as "Goulac." In the first series of tests, failure was prevented by the addition of 1.6 g of sulphite residue per 100 g of water. Further tests showed that this same amount offered protection when the sodium silicate concentration was 0.8 g per 100 g of water. In the last test, the sulphite residue protected the steel even when the applied stress was 50,000 lb per sq in.

The total solids from a sulphite waste liquor would normally contain approximately 60 per cent lignin, 15 or 20 per cent of various sugars, a small amount of calcium and minor amounts of other materials.[6]

One gram of lignin sulphonate per 100 g of water stopped failure at 50,000 lb per sq in. With 2 g protection was secured at 60,000 lb per sq in. or at 50,000 lb per sq in. in the presence of chloride. Failure was prevented by 4 g of this material when the sodium silicate was as high as 3.2 g per 100 g of water. It would seem that lignin is one of the main protective constitutents in the residue from the sulphite waste liquor.

The last two experiments with 50 g of sodium hydroxide per 100 g of water deserve especial attention. This solution destroyed all protection offered by sodium sulphate even when the stress was applied at room temperature, yet protection by lignin sulphonate existed even when the specimen was stressed at 250 C.

Two tests each were tried with magnesium lignin sulphonate[7] and calcium lignin sulphonate.[7] The magnesium compound was not quite as effective as lignin sulphonate and, while the calcium compound prevented failure, it does not seem desirable for boiler use.

Tests were made at three temperatures with a concentrated-sulphite waste liquor[8] that was not evaporated to a dry solid but was left as a viscous liquid. Failure was prevented in all cases regardless of the temperature, silica concentration or applied stress. This material is more satisfactory than lignin sulphonate, since autoclaving at elevated temperature is unnecessary to prevent failure.

While the lignin compounds and the concentrated sulphite liquors seem to offer quite satisfactory protection against intercrystalline cracking up to 250 C they must be investigated further. Their protective action should be determined after evaporation from dilute to concentrated solution. Their possible decomposition products must be studied especially at pressures above 500 lb per sq in., and means should be developed for testing the boiler water for the agent that is protecting the steel. In boilers operating at pressures above 400 lb per sq in. gage carbonaceous scales have been reported when the feedwater contained organic compounds, presumably including lignin. This may be another factor that will limit the temperature at which these materials can be used.

Three tests have been made to see if chestnut and oak extracts would prevent intercrystalline cracking, but the results did not indicate any beneficial influence. These tannins belong to the depside or gallotannin class.

A series of tests was made with Philippine cutch at three different temperatures. With 2 g per 100 g of water, protection was secured in all cases.

It was found that quebracho will protect the eccentric-grooved specimens at 250C with any stress below 60,000 lb per sq in. Failure was stopped at 150 C, with 3 g of quebracho per 100 g of water.

The results with quebracho and Philippine cutch indicate that these compounds may offer a second series that is comparable to the lignin compounds in stopping attack. Both quebracho and cutch belong to the phlobatannin class.

Conclusions

1. A high concentration of sodium sulphate will prevent failure of boiler steel in the tension tests in sodium hydroxide-sodium silicate solutions if two conditions are satisfied: (a) the stress in the metal does not vary materially while it is in contact with the solution at elevated temperature, and (b) the sodium-hydroxide concentration does not greatly exceed 25 g per 100 g of water. No difference was found between the action of a saturated solution of sodium sulphate and one also containing loose crystals of solid.

Sodium sulphate dissolved, or present in excess as loose crystals did not prevent failure between 150 and 250 C if either condition (a) or (b) was violated.

2. Attempts to prevent cracking by filling a capillary space with solid sodium sulphate to exclude the solution were not successful. Without further substantiating evidence, this single series of tests cannot be interpreted to mean that it is impossible to plug a boiler seam with sodium sulphate. Further tests will be run under experimental conditions that more nearly duplicate a riveted joint.

3. A saturated solution of sodium sulphate will prevent failure of U-bend specimens in sodium hydroxide solutions containing sodium chromate, but not in those containing lead oxide. Apparently, the inhibiting action of the sulphate is sufficient to stop the sodium hydroxide-

[6] A. M. Partansky and H. K. Benson. Technical Association of the Pulp and Paper Industry, pp. 29–35, February 13, 1936.
[7] Furnished by Marathon Chemical Company, Rothschild, Wis.
[8] Furnished by West Virginia Pulp and Paper Co.

sodium chromate attack but will not stop the more severe and more powerful action of the solution containing lead oxide.

4. Sodium phosphate will not prevent failure in the tension tests unless the sodium silicate-sodium hydroxide ratio is well below that encountered in most feedwaters, and even then the stress in the steel must be entirely uniform at elevated temperature. Sodium phosphate will not stop cracking in the U-bend tests with sodium hydroxide-lead oxide solutions.

5. No inorganic salts with the exception of oxidizing agents have been found to prevent failure under conditions of changing stress at elevated temperature and with sodium hydroxide solutions containing appreciable amounts of sodium silicate.

6. Chestnut extract, oak extract and tannic acid did not prevent failure of the tension specimens when the stress was applied at elevated temperature.

7. Lignin sulphonate, concentrated sulphite waste liquors, Philippine cutch and quebracho did prevent cracking even when a very high stress was applied at elevated temperature. Protection was not destroyed by high sodium silicate or high sodium-hydroxide concentrations. The sulphite liquor was found to be suitable at all temperatures up to 250 C, but in the case of the other compounds it was found that definite temperature ranges had to be observed. It also was found that for each compound specific concentrations were required for maximum effectiveness. In the U-bend tests, lignin sulphonate and concentrated sulphite waste liquor were superior to Philippine cutch and quebracho.

The cracking of steel in an intercrystalline manner seems to depend on the combined action of a number of factors and the rate of attack may be varied from one going through a thick section of steel in hours, to one requiring days or weeks to produce visible cracking and, finally, to one causing no intercrystalline attack upon the steel at all.

Rating of Protective Agents

Similarly, it would be expected that various inhibiting chemicals would have degrees of effectiveness depending both on their own action and on the factors that produce cracking. The agents mentioned in this paper can be given a tentative protective rating depending on their influence in the presence of relatively high silica, temperature of stress application, temperature range in which they must be used and their action in sodium hydroxide-lead oxide solutions. The position of sodium sulphate and other inorganic salts in this list is determined by their action in solution rather than any possible mechanical plugging they may cause. From least effective to most effective the list would be as follows: (1) sodium carbonate, (2) sodium phosphate, (3) sodium sulphate, (4) quebracho and Philippine cutch, (5) lignin sulphonate and (6) concentrated sulphite waste liquor.

The experimental work now shows that if the combined factors produce severe and rapid cracking, a substance well down in the list of protective agents must be selected to stop the attack. In boiler operation, sodium sulphate could be satisfactory in some instances and not in others, and the controversy about the action of this salt, which has been as widely employed as an inhibitor, probably arises from lack of information regarding the conditions that actually caused cracking.

Midwest Power Conference Scheduled for April

From Armour Institute of Technology comes the announcement that a Midwest Power Conference will be held in Chicago, April 13–15, 1938, under its sponsorship in cooperation with six midwestern state universities. This replaces the set-up of the former conferences which were organized under private and commercial sponsorship.

The program planned for the conference will involve some thirty papers presented by accepted authorities drawn about equally from educational and industrial fields. Emphasis will be divided between steam, diesel, electric and hydraulic power. In each field papers will be presented which discuss the best modern practices while others will venture into the picture of the future as indicated in the investigations of our great research laboratories.

Of peculiar interest in these days of great advance in power production will be a paper surveying the Power Requirements of the Nation. Two papers presenting various phases of the controversial subject of Valuation of Power Plants will be heard with unusual interest. Equally controversial from the technical point of view will be the discussion of steam versus diesel power for driving modern streamline high-speed trains.

The Midwest Power Conference is open to all who are interested in power problems either from the technical, sales or production points of view. Registration and headquarters will be at the La Salle Hotel, Chicago, Illinois. Entertainment and social features will be provided such as a smoker, the banquet and several luncheons for various groups. There will also be entertainment provided for the ladies. It is the intention to collect all papers presented at the Power Conference into a printed Proceedings which should continue on an annual basis. Details of the program arrangements are being handled by L. E. Grinter, Dean of the Graduate Division, Armour Institute of Technology, Chicago, Illinois, who will act as director of the Conference.

New York City Asks Suspension of Coal Prices

Mayor La Guardia of New York has applied to the National Bituminous Coal Commission, through the Consumers' Counsel, for suspension of prices fixed by the Commission for coal entering the city. The petition alleges that the increase of twenty cents a ton in the coal prices will increase the cost of operation to the city of its transportation lines, public buildings, institutions, street lighting, fire alarm systems, etc., to the extent of a million dollars annually. Many times this amount will be involved in increased cost to industries and to utilities in which the city's revenues are involved.

The petition is based on the ground that the method pursued by the Commission in selling prices, without public hearings and findings of fact, violates the Constitution in that it deprives the city and its citizens of the money involved through the increase without due process of law.

Operating Experiences at Burlington Generating Station

By JOHN A. INWRIGHT,

Superintendent of Burlington Generating Station, Public Service Electric & Gas Company

Abstract of a paper presented before the Metropolitan Section, A. S. M. E., New York, January 18, 1938. This superposed installation has been in operation for the past six years. In certain respects it presents a contrast to topping units of more recent design, particularly its riveted boiler drum and the double-deck tube arrangement. Although in later boilers of this type the upper deck is omitted, the alterations in tube arrangement of the Burlington unit to eliminate tube starvation are of interest. Installation of a steam scrubber in September 1933 eliminated troublesome deposits on the turbine blades. The station heat rate when burning oil has ranged from 14,636 to 14,928 Btu per kwhr and when burning coal is 15,220 Btu; compared with 22,824 Btu per kwhr before superposition.

THE superposed unit at Burlington Generating Station has been in service since February 17, 1932. The principal equipment consists of a 600,000 lb per hr, 730 lb pressure, 850 F, Walsh-Weidner cross-drum, sectional- header type boiler with an Elesco superheater of the interdeck type, a plate-type air heater and a 22,500-kva Westinghouse 3600-rpm turbine-generator taking steam at 650 lb, 825 F and exhausting at 205 lb to the low-pressure station header.

The boiler was designed for operation with pulverized coal, but shortly after being put in service it became economically desirable to burn oil as well. Accordingly, oil burners were installed in combination with the coal burners. During the first five years' operation a total of only 130,000 tons of coal was burned. This was less than a normal year's consumption for coal alone. Since April 1937, however, coal has been burned continuously, but this period has not been long enough to permit reliable figures on maintenance of the pulverizing equipment.

Following the early adjustment period, the unit was in continuous operation from August 19 to December 15 during which period considerable carryover of solids in the steam was noted. This resulted in deposits on the turbine blades which affected its capacity as much as 15 per cent during one month's operation. Therefore, in September 1933 a steam scrubber of the baffle type was installed in the drum. At the same time the water column connections were lowered 5 in. so that the required operating level would be within the range of the gage glass. With these changes it was possible to maintain a solid content in the steam of less than 1 ppm at all loads with a concentration in the boiler water of 800 ppm. There is still a slight amount of scale deposited on the turbine blades, but in a year's operation this has little or no effect on the turbine capacity and is easily washed off at the time of annual overhaul. Figs. 1 and 2 show the condition of the turbine blading before and after the installation of the scrubber.

The tube arrangement of the boiler as originally built was 14 tubes high and 56 headers wide above the interdeck superheater and alternate headers containing six and two tubes below the superheater. The latter were designated as "long" and "short" headers, respectively.

In the summer of 1934, following evidence of starvation in certain tubes, investigations were made to determine the conditions obtaining inside the tubes. Thermocouples were peened on top of the tubes and water

Fig. 1—Turbine blading before installation of steam washer

Fig. 2—Turbine blading after installation of steam washer

sampling connections were made through holes drilled in the tube cap studs. In the row directly below the superheater the tubes in the short header sections showed temperatures of 30 or 40 deg F above the saturated steam temperature and a concentration equal to that of the drum. Certain tubes in the long header section showed temperatures up to 800 F and concentrations up to ten times that of the water in the drum. The concentrations in these tubes began to increase at 200,000 lb per hr steam flow, and the tubes began to show signs of heating at loads of 400,000 lb per hr.

The changes in tube arrangement that were subsequently made entirely eliminated all tube starvation below the superheater. These changes (see Fig. 3) consisted in removing the tubes in the long header section of the row directly below the superheater and all the tubes in the row immediately above the superheater. In the long header sections curved tubes were installed running from the rear header of the row below the superheater to the front header of the row directly above the superheater. The tube holes in the front and rear headers below and above the superheater, respectively, were plugged.

These new curved tubes contained a straight section about 2 ft back of the original vertical baffle. A small horizontal header was installed at an elevation about opposite the next to the bottom loop of the superheater, and from the front headers of the short sections curved tubes were run to this header. The vertical section of these tubes was directly behind the superheater, in the approximate location of the old vertical baffle.

Special tile were placed between the tubes of the long header sections forming a water-cooled baffle, and tile were also installed in the vertical row of the short header tubes immediately behind the superheater. This formed a 2-ft bypass around the superheater, in which adjustable dampers were installed for superheat control. In this way a three-fold object was accomplished—the circulation difficulty was corrected, close superheat control was attained and the water-cooled baffle that would stand up well replaced the old baffle constructed of cast-iron frames filled with refractory material which had given trouble.

Dampers of Farhite N7 containing 3 per cent nickel and 28 per cent chromium have replaced the earlier dampers of Farhite N3 containing 35 per cent nickel and 15 per cent chromium. With a temperature in this zone of 1950 to 2000 F when burning oil the Farhite N7 dampers lasted about a year, the deterioration apparently being due to the presence of vanadium oxide in the oil residue. When burning coal, however, the material appears to be practically unaffected by the high temperature. The dampers have lately been relocated at the top of the bypass passage but their length of service in this location has been too short to afford any information as to their life.

During the early period of operation there were some superheater tube failures mostly due to accumulations of scale.

A number of different materials for soot blower elements have been tried in locations below the superheater, but none would stand up more than six months. The latest type, which is now being tried out, consists of a pipe laid on top of each of the boiler tubes in the row below the superheater (see Fig. 4). These pipes are held in place by a number of clamps welded to the tubes. Five blowing nozzles are spaced along each blower pipe and are fed by a manifold header located outside the boiler casing. This arrangement has stood up well since its installation in October 1937 and seems quite effective. It is necessary, however, to supplement the soot blowers by hand lancing in which water at 50 to 60 lb pressure is used. A rotating, retractive type soot blower using saturated steam is now being tried out to remove slag accumulations on the furnace walls.

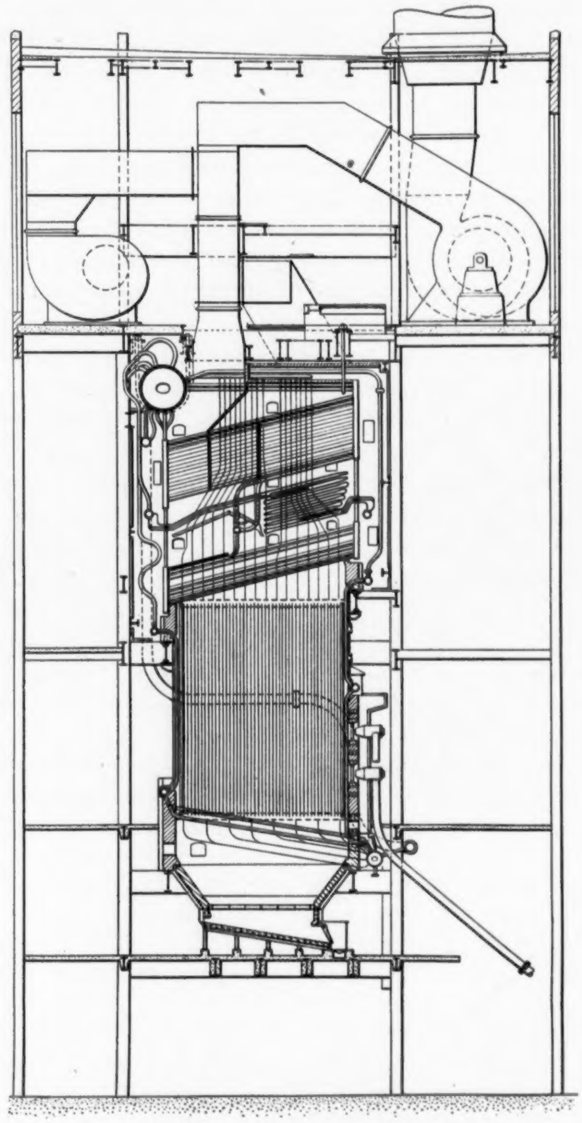


Fig. 3—Section through boiler after rearrangement of tubes to rectify starvation

During the period of operation on coal one set of inlet vanes and one set of impeller vanes have been changed on the induced-draft fan. The second set will have to be installed this spring.

A precipitator has lately been installed between the air heater and the induced-draft fan and this, no doubt, will cut down the induced-draft fan maintenance.

After nearly five years' operation with oil the plates of the air preheater are in such bad condition that they will either be replaced or a new air preheater will be installed this year.

The high-pressure boiler has been in service 44,393 hr up to January 1, 1938, with an availability of 88.3 per

cent. Of the 11.7 per cent unavailability, 7.64 per cent was due to inspection, 2.48 per cent to alterations, 1.21 per cent to forced outages and 0.36 per cent to other apparatus. The alterations included the installation of the steam scrubber, the water-cooled interdeck baffle and superheater bypass and the soot precipitator.

The High-Pressure Turbine

The first high-pressure turbine-generator was in service 5731 hr during the eleven months of its existence, during which its availability was 73.2 per cent. Following an outage from December 15, 1932 to January 21, 1933, to rebuild the high-pressure seals and dummies, the unit had been back in service only 34 hr when heavy vibration broke an oil line and the oil coming in contact with the hot casing caught fire and completely ruined the machine.

A new turbine of improved design was installed and placed in service October 28, 1933. Two days later it was carrying full load. This turbine was furnished with Aroclor as the hydraulic medium for operating the control valves, although oil is used on the bearings. The seals are of the "end tightened" design which requires that the shaft be moved forward when the machine is in service at running temperature, and moved back when being taken out of service.

Fig. 4—Soot blower elements clamped to boiler tubes below superheater

The size of this high-pressure unit is such that it will supply all the steam required to carry full load on the three 12,500-kva low-pressure turbines. The normal operation is to run with the governors wide open on the low-pressure units, and to control the station load by the governor of the high-pressure turbine. The back pressure, therefore, varies with the load. At times, as conditions require, the low-pressure turbines are cut out, or in, in the same manner as though the steam were supplied by the low-pressure boilers.

The high-pressure turbine seals are not designed to withstand full back pressure with the shaft at rest. In fact, the back pressure is seldom allowed to build up over 100 lb until the shaft is in the running position. Usually the high-pressure turbine is started as a compound unit with one of the low-pressure machines.

Because of operating the station at variable back pressure, special arrangements have to be made to supply steam for the vital auxiliaries of the low-pressure turbines, such as the auxiliary oil pumps and the steam-jet pumps. Steam for this purpose is taken from the saturated header of the high-pressure boiler and reduced to 200 lb through a $2^1/_2$-in. reducing valve.

The availability of the first turbine was 73.2 per cent, whereas the present turbine has been in service 32,151 hr, or 87.8 per cent of the time since its installation, from October 1933 to January 1, 1938, with an average hourly output of 15,000 kva. Its availability has been 90.4 per cent. Of the total outages of 9.6 per cent, 8.4 per cent were for annual overhaul and 1.2 per cent were forced outages. The reasons for these forced outages are as follows:

1933—Primary valve (2), bearings (1)
1934—Primary valve (5), bearings (2), governor (3), generator brushes (2)
1936—Governor (1), balancing (1)
1937—Generator brushes (1), balancing (1)

The Hagan reducing valve between the high-pressure boiler and the 200-lb system has had approximately 6400 hr of service. During 1933 while the new turbine was being installed it ran almost continuously for some 5000 hr. The average steam flow through it has been 210,000 lb per hr with a maximum of 350,000 lb per hr. The operation of this pressure-reducing valve has been satisfactory but the automatic temperature control has not been altogether reliable and changes are contemplated.

The performance of the station is given in the following tabulation:

PERFORMANCE COMPARISON

Time and Conditions	Average Load—Kw	Maximum Load—Kw	Load Factor	Btu per Net Kwhr
February 1928 Before Superposition	23,500	32,200	73	22,824
December 1935 After Superposition	39,000	55,000	71	14,824
May 1928 Before Superposition	18,900	21,800	87	22,244
February 1933 With Reducing Valve	18,500	22,500	84	20,780
April 1936 With Superposition	28,800	35,000	82	14,928
May 1935 Burning Oil	43,500	50,000	87	14,636
October 1937 Burning Coal	38,000	45,000	84	15,220

Earl C. Robertson has been elected vice president of the Pittsburgh Coal Company, in charge of sales, succeeding H. E. Booth, resigned.

Joseph A. Messenger, formerly with United Engineers & Constructors, Inc. of Philadelphia, has been appointed general manager of the Buell Engineering Company, Inc., New York, manufacturers of fly ash eliminators and dust collecting systems.

Timothy A. Kenney, vice president of the Commonwealth & Southern Corporation, died on January 19, after a long illness, at the age of 55. He was long identified with the public utility field, his earlier connections having been with the Hudson River Power Transmission Company, the Adirondack Water Power Corporation. He joined the Consumers Power Company in 1912 and in 1916 became associated with Hodenpyl, Hardy & Company of New York, one of the predecessors of the Commonwealth & Southern Corporation.

Resistance Welding of Boiler Tubes

Several methods are in use for making boiler tubes. Among these is that of resistance welding by the Johnston process, the product of which is marketed under the trade name "Electrunite" tubes. How these tubes are made will probably be of interest to many power plant men, particularly in view of the recent installation of a new type of continuous controlled-atmosphere furnace for normalizing and bluing the tubes at the Cleveland plant of Steel and Tubes, Inc., a subsidiary of the Republic Steel Corporation.

Briefly, in the Johnston process the flat-rolled plate, cut accurately to the proper width, is passed through a series of rolls of varying contour to produce a butted tube. This is then passed directly under a pair of copper disks which act as electrodes, one disk making contact with the surface of the tube on each side of the seam. The lower half of the tube under the electrode is supported by a pair of steel rolls which exert pressure on the sides of the tube at the instant of welding and force the edges of the seam together. The welding heat is generated by the resistance of the joint and no extra metal is added. The slight upset or burr formed at the weld is removed by cutting tools both inside and outside the tube. Test specimens are taken while the tube is being welded. The process is continuous and includes forming, welding and sizing immediately after welding.

Fig. 1 shows the machine employed to effect these operations.

Normalizing Process Employed

In order to obtain uniformity of microstructure and hardness, the tube is normalized at above the critical point of the metal. Normalizing recrystallizes the steel, relieves cold-working and welding stresses and produces a homogeneous fine-grain microstructure of uniform hardness.

Formerly by normalizing in an ordinary electric furnace at 1650 F a light loose scale was formed on the surface of the tube and pickling was necessary to remove the scale. This resulted in a dull surface that was not as resistant to corrosion as that before normalizing and pickling. Therefore, in order to preserve the original finish the annealing is now done in a special reducing atmosphere.

Controlled Atmosphere Furnace

The new furnace, shown in Fig. 2, is suitable for both annealing and normalizing, as it has a temperature range of 1300 to 1800 F. It is heated by means of horizontal gas-fired radiant-tube heating elements located both above and below the roller hearth conveyor. The

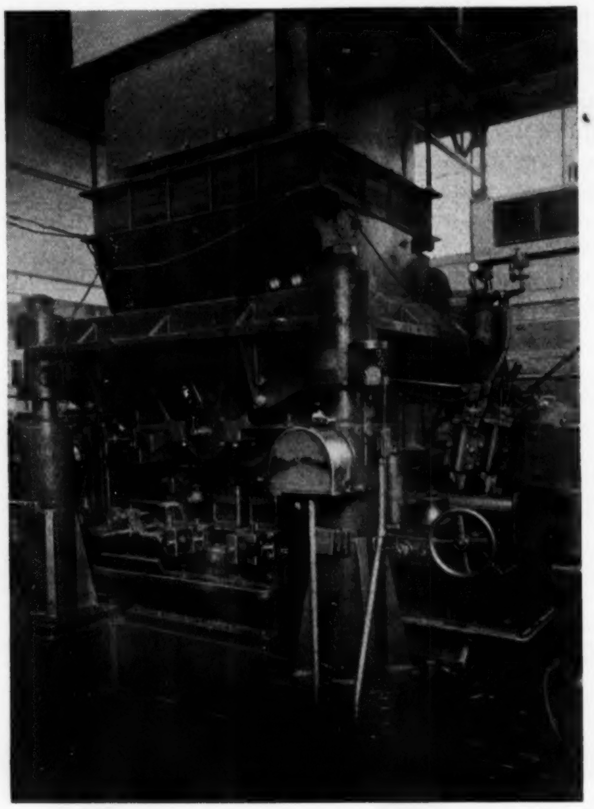


Fig. 1—Johnston welder showing rotating disk-type electrodes and outside burr cutter

boiler tubes are surrounded by a prepared atmosphere which prevents oxidation and gives the tubes a bright luster. To accomplish this the gas is confined within cylinders or tubes of alloy steel which become incandes-

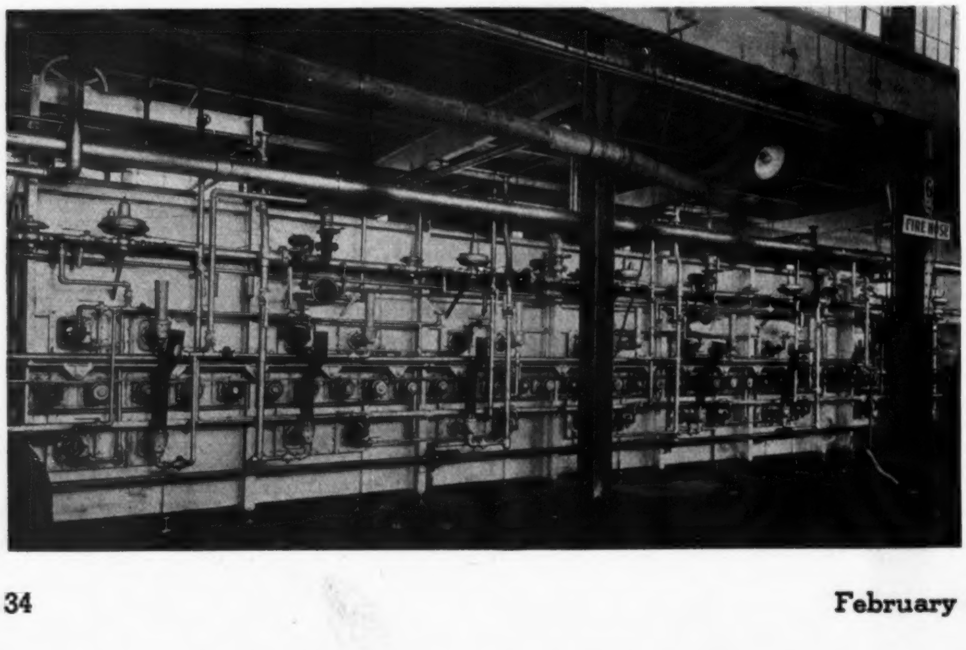


Fig. 2—Gas-heated, controlled-atmosphere normalizing furnace

cent and radiate heat to the work. At the discharge end of the heating chamber and integral with it is a cooling zone that is water-cooled and filled with the reducing atmosphere, the purpose of the cooling zone being to reduce the temperature of the tubes below the point where oxidation will take place upon leaving the furnace.

Reducing Atmosphere of Inert Gas Is Separately Prepared

The reducing atmosphere is prepared in a unit separate from the furnace and is made by cracking natural gas fuel which is further refined by scrubbing, filtering, removing sulphur and dehydrating. The resulting gas is non-explosive and will not break down at high temperature. It is free of oxygen and is fed into the furnace and cooling chamber slightly above atmospheric pressure so that all leakage is outward.

The tubes after leaving the normalizing furnace continue on the roller conveyor across a space for inspection to a bluing furnace where a thin blue oxide coating, similar to that in a gun barrel, is imparted to the surface. The purpose of this bluing operation is to provide some measure of protection against rust while the tubes are in storage or during shipment and also to impart a distinctive color to them.

After leaving the bluing oven the tubes continue on the conveyor to the processing building where they pass through straightening rolls and are cut off to the desired lengths.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Selection of Power Plant Materials

The desire to be independent of importations and to minimize shortage of certain materials is responsible for a careful study now being made in Germany of the materials that enter into the construction of power plant equipment. An interesting account of such a study is given by Dr.-Ing. E. Schulz in the December 4, 1938 issue of *Zeitschrift des Vereines deutscher Ingenieure.* In this article minimum weights of material per unit of output are suggested as a guide in power plant construction, and consideration is given to representative groups of materials and alloys in use as well as the difference between finished and unfinished weight.

With reference to boilers, a chart (not reproduced) shows for temperatures up to 800 F, the relative amounts of iron, silicium, manganese and aluminum entering into the steel, and for higher temperatures the percentages of chromium, molybdenum, vanadium, copper and nickel required. The extent to which each of these is produced at home or must be imported is indicated, as well as those in which home production is being expedited or improved. Obviously, designs that minimize or eliminate imported materials are encouraged.

By way of example as to how weights of marine boilers (exclusive of water) have and can be reduced, those of the old liner Imperator (now the Berengaria) built in 1912, weigh nearly 8 lb per pound of steam evaporated per hour as compared with those of the Bremen (1929) which weigh 3.9 lb per pound of steam and, further, those of the Scharnhorst (1935) weighing 2.5 lb per pound of steam.

Higher steam pressures incur an increase in the weight of the boiler per unit of output whereas the greatest reduction is brought about by increased rating; the latter practice having resulted in a reduction of approximately 40 per cent for stationary boilers during the past twenty years despite increases in pressure.

The accompanying table gives the relative weights per unit of output for the boilers shown in the sketches. It is pointed out that other high-pressure boilers of special design, including several of the forced-circulation type, employ considerable amounts of alloy steels and it is hoped to minimize these requirements for those alloy metals that are not produced in quantity in Germany.

It is observed from the table that high-pressure drums represent from 14 to 20 per cent of the total weight; that the economizer and air heater together represent the largest proportion of the weight; that the weight of superheaters is relatively small and requires special materials only when steam temperatures of 840 F are exceeded; and that the structural supports and casings account for the greatest weights.

The article also discusses the use and strength of materials used in steam turbines and includes comparative weights of different types of turbine construction.

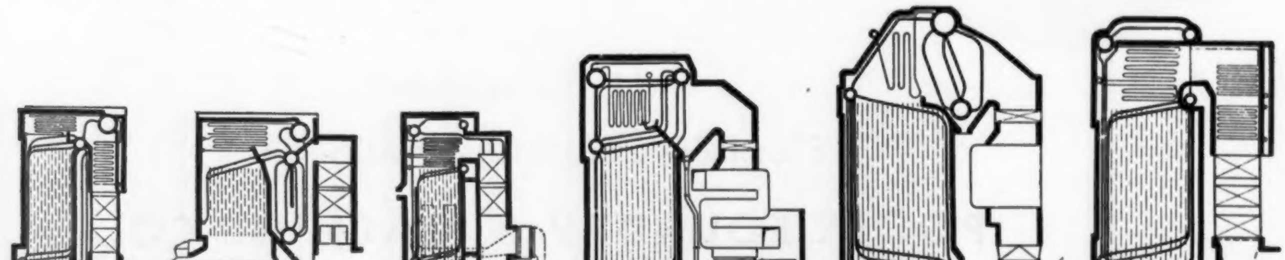
WEIGHT PER POUND OF STEAM PER HOUR OUTPUT FOR BOILERS SHOWN BELOW

	A	B	C	D	E	F
Output, lb per hr	66,000	70,500	110,000	198,000	220,000	265,000
Pressure, lb per sq in.	480	558	1,320	380	250	1,985
Steam temperature, F.	825	770	875	800	788	932
Steel, lbs.						
Drums	0.50	0.83	1.27	0.37	0.31	0.65
Tubes	0.50	0.58	0.67	0.52	0.47	0.46
Superheater	0.26	0.15	0.34	0.20	0.13	0.36
Economizer	0.23	0.88	0.48	0.29	0.51	0.27
Air heater	0.97	0.39	0.53	1.00	0.90	0.71
Refractory	0.12	0.13	0.16	0.07	0.07	0.13
Structural	1.08	1.32	1.60	0.70	0.54	0.89
Casing	0.59	..	1.48	0.91	0.80	0.49
Total, lb (exclusive of insulation)	4.25	4.28	6.53	4.06	3.73	3.96

Why Exceed 1000 Lb per Sq In.?

In the January 1938 issue of *The Power and Works Engineer* Prof. A. L. Mellanby, well-known British engineer, discusses the relative thermal efficiencies obtainable from steam turbine plants with various pressures and concludes that little, if any, gain can be expected by going beyond about 1000 lb per sq in. for a condensing installation.

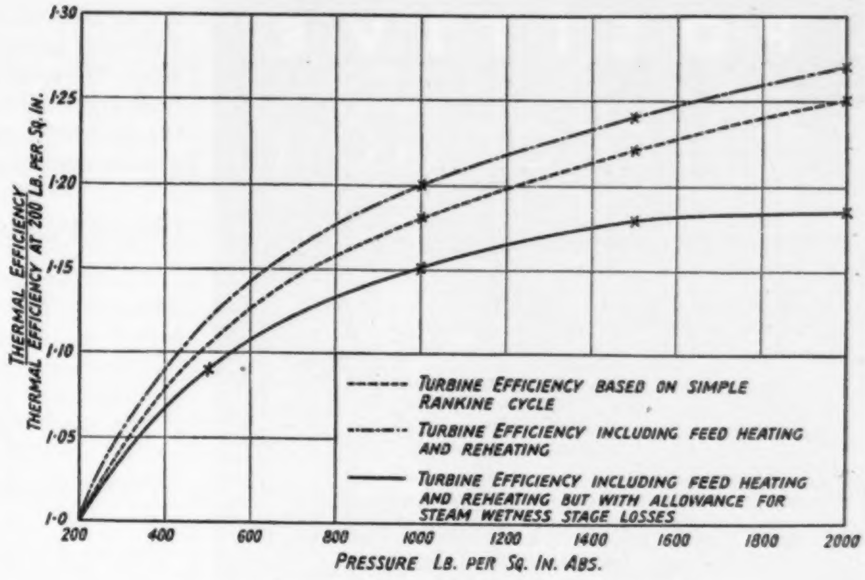
Assuming the efficiency at 200 lb per sq in. as unity, and a steam temperature of 900 F, the author has plotted three curves for initial pressures up to 2000 lb per sq in. These show, (1) the turbine efficiency based on the simple



Sketches of boilers whose weights are given in table

Rankine cycle, (2) that including feed heating and reheating and (3) that including feed heating and reheating but with allowance for steam wetness stage losses. The values are given in percentages of the efficiencies at 200 lb. While the curves indicate a continual rise in thermal efficiency with rise in pressure, it will be noted that the improvement between 200 lb and 1000 lb is appreciably greater than that between 1000 lb and 2000 lb.

Referring to a temperature-entropy chart, it is shown that, as the initial pressure is raised, the tendency is toward an increasing proportion of the expansion taking place in the wet field, as well as an increasing part in the high-pressure range, which means that at both ends of the expansion there are influences at work tending to reduce the efficiency of the turbine. The effect of pressure on stage efficiency may to some extent be realized by considering first the losses in any stage, which include nozzle loss, disk loss, blade loss and leakage loss. By careful analysis it is possible to determine the degree to which these losses are influenced by pressure. Such calculations give quite a different picture from that obtained by considering only the ideal cycle efficiencies for the pressures given.



Comparative efficiencies plotted against pressure

The results of such calculations, applied to a single-stage reheating cycle, with a number of feed heaters to cover in each case a temperature range of about 50 deg F, are indicated for the actual turbine alone by the solid curve. From this it will be seen that, considering the efficiency at 200 lb as unity, the values at 500, 1000, 1500 and 2000 lb are, respectively, 1.09, 1.15, 1.18 and 1.185.

However, account must be taken of the feed pump and of the boiler efficiency, the former producing an appreciable reduction in efficiency as the pressure increases. Assuming that the boiler efficiency is constant and taking into account only the feed pump, the increase in efficiency of the plant would be only about 3 per cent as the pressure rises from 1000 to 2000 lb per sq in.

Professor Mellanby also points out that the heat content of a pound of 900 F steam is less at 2000 lb than at 1000 lb and that the adiabatic heat drop to 0.5 lb per sq in. is 600 Btu for the former condition and 584 Btu for the latter, or less than 3 per cent difference. From this analysis he concludes that many of the claims for extremely high pressures are justified only on the basis of the ideal cycles without taking into account the inevitable losses that are present when the actual installation is considered.

Performance of British Power Stations

The following table prepared from the report of the Electricity Commissioners for the year 1936, is reproduced in part from the January 1938 issue of *Engineering and Boiler House Review* (London). It gives the average fuel consumption per net kilowatt-hour, thermal efficiency, maximum load and station load factor of the more important British power stations, all of which, with the exception of the Tir John Station at Swansea, show a thermal efficiency of 20 per cent or over. It will be noted that Battersea Station of the London Power Company again heads the list with a net thermal efficiency of 27.63 per cent and an average fuel consumption of just under a pound of coal per kilowatt-hour.

PERFORMANCE OF LEADING BRITISH POWER STATIONS

Stations	Average fuel consumption coal per unit sent out	Thermal efficiency (approximate) based on units sent out	Maximum load sent out by generators during year	Station load factor based on units sent out
	Lb	Per Cent	Kw	Per Cent
Battersea	0.97	27.63	186,300	60.8
Dunston B	1.13	26.87	114,500	63.1
Barking B	1.17	26.54	147,600	68.2
Clarence Dock	1.16	25.39	101,400	67.5
Ironbridge	1.51	24.98	101,000	50.3
Spondon	1.40	23.34	81,960	55.2
Deptford West	1.34	22.94	127,750	50.9
Portishead	1.11	22.74	87,220	38.2
Kearsley A	1.24	22.68	59,100	70.2
Blackburn Meadows (New)	1.28	22.19	53,590	52.7
Thornhill	1.38	21.76	58,560	45.2
Hams Hall	1.62	21.71	158,600	44.6
Kirkstall	1.43	21.19	50,000	54.8
Barton	1.35	21.11	112,120	66.4
Brimsdown B	1.48	20.93	103,100	35.9
Portobello (Edinburgh)	1.52	20.90	99,400	42.9
Ferrybridge	1.42	20.84	43,590	58.6
North Tees	1.42	20.43	80,400	30.0
North Wilford	1.65	20.22	61,600	47.2
Barking A	1.53	20.14	208,400	49.4
Lots Road	1.54	20.00	103,834	44.7
Tir John (Swansea)	1.48	17.99	45,000	46.2

Overfire Air

An article by K. Cleve in the November 15 issue of *Feuerungstechnik* discusses the results of some experiments to determine the most effective pressures and nozzle openings for the admission of secondary air over a traveling-grate stoker. It was found that for a given power expenditure the larger diameter nozzle produced a higher central velocity of the jet as well as a greater volume, whereas with a very small nozzle not only was the extent of the mixing space limited but the movement of the air beyond the nozzle was restricted and a large part of the energy was converted into heat. However, if high pressures are to be employed a small nozzle opening becomes necessary in order to keep within desirable limits the volume of air admitted as well as the power expenditure. Because of the small ratio of over-

fire air to total air in the furnace, the difference between a circular and a rectangular form of nozzle is inappreciable. However, reducing the distance between nozzles from about 3 ft to 18 in. reduced the dead space between the jets and produced greater turbulence of the air and gas streams by overlapping.

Rapid Feedwater Treatment

A late development in German methods of feedwater treatment, characterized by means for shortening the period of chemical reaction, is described by Dr. A. Splittgerber in the November issue of *Archiv für Wärmewirtschaft und Dampfkesselwesen.*

The sketch shows the feedwater equipment (left) as applied to a La Mont forced-circulation boiler (right). Referring to the reference letters, *a* is a feedwater heater

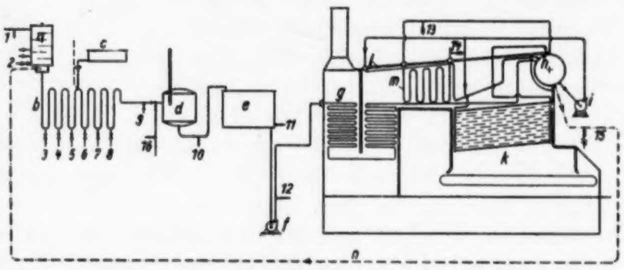


Diagram showing feedwater equipment

of the cascade type, *b* a tubular softener, *c* the phosphate container, *d* the silica filter, *e* the feedwater tank and *f* the feed pump. As to the steam generating unit, *g* is the economizer, *h* the drum, *i* the circulation pump, *k* the boiler tubes, *l* the roof, *m* the superheater and *n* the return from the boiler.

Raw water enters the heater at point *1* and is heated to about 210 F by steam in the lower third of the cascade. At the bottom, below the sampling point *2* a certain amount of the recirculated boiler water is added to the hot makeup water. The hot water flows through the entire tubular softener *b* to the silica filter. The hardness remaining after leaving the heater is partly removed en route from sampling points *3* to *5* by the alkalines remaining in the recirculated boiler water, and midway along the tubular softener a phosphate solution is added from tank *c*. The softening is thus completed between sampling points *6* and *9*. The separated sludge is drawn off and filtered.

Rise in pressure within the filter is measured by a glass manometer which serves as a gage for washing the filter, the period of washing requiring about 20 min for each 20 to 24 hr run. The softened and filtered water is delivered to the feed tank *e*, thence by the feed pump to the economizer at about 208 F. It enters the boiler drum at 515 lb pressure. Samples are also taken at points *13*, *14* and *15* in the saturated steam line, after the superheater and also in the return line *n* from the boiler to the heater.

At an hourly rate of 192 cu ft of raw water (containing 9 deg carbonate hardness and 2.3 deg of non-carbonate hardness) and 39 cu ft of recirculated boiler water, making a total of 231 cu ft, 10 g of commercial tri-sodium phosphate (19.3 per cent P_2O_5) were required to soften 35.32 cu ft of water. At this rate of flow a total of 58

sec was required for complete softening within the tubular elements. Filtration required about 11 min. The measured velocity through the tubular softener was approximately 100 ft per min.

The author believes that the rapidity of chemical reaction is brought about principally by catalytic action of the iron walls of the small tubes through which the water flows at high velocity. He states it to be analogous to the removal of organic matter in solution from water by means of an aluminum floc without settling basins, where filtration may begin within a few seconds after the addition of the chemicals.

Topping Unit for Paper Mill

A recent issue of *Wärme* describes a high-pressure "topping" extension to the Renkum mill of the Van Gelder Paper Company, consisting of three 66,000-lb per hr boilers operating at 1060 lb pressure and 840 F total steam temperature. Steam is supplied to a 3600-kw high-pressure turbine-generator which exhausts to three existing low-pressure condensing turbines of the extraction type. The process requirements of the mill are about 60,000 lb of extracted steam per hour at 20 to 28 lb gage. The topping installation is said to effect a saving of approximately 18,000 tons of coal per year.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Axial Flow Fans

By Kurt Keller

Adapted from the German text by Lionel S. Marks assisted by John R. Weske

This work is based on investigations made by the author at the laboratories of the Escher Wyss Company of Zurich and deals with the complete axial-flow fan unit, consisting of the inlet, the guide vanes, fan wheel and the diffuser. The elementary airfoil theory is employed to establish the relations between pressures, volumes and efficiencies. The mutual interference of the airfoil grid is also considered. Performance data are included on a series of axial-flow fans having 4 to 20 blades with both the guide vanes and the runner blades adjustable for angular setting. The test results show that single-stage, axial-flow fans can be calculated accurately by means of this elementary theory and that it is only in the case of fans having a large number of blades, intended for high pressures, that mutual interference in the airfoil grid becomes sufficiently large to justify modification of the theory.

The book is essentially one for designers, and Professor Marks, in adapting the text to this purpose, has omitted or abstracted some of the original material on research.

There are 140 pages, 6 × 9 in., numerous tables and 112 illustrations. The price is $4.

Thermodynamics

By H. A. Everett

Professor of Mechanical Engineering, Pennsylvania State College

This book presents an exposition of the fundamental subject of engineering thermodynamics sufficiently comprehensive so that the student of engineering upon mastering and assimilating its contents will have a good working knowledge of this important science upon which can subsequently be built an understanding of the design and operation of power plant, refrigerating and air conditioning equipment.

In the preparation of this treatise the author has developed the subject from its fundamentals. No effort has been spared to make the text full and complete where such is necessary to properly explain the steps taken. Since the book is designed for students having a good mathematical background, mathematical analyses are given in complete detail. The entire book is profusely illustrated with figures, diagrams and graphs. The solutions of practical problems are presented in full at all points where such material would help the student to understand the application of the material.

Especially is the book well developed in its earlier pages wherein the elemental material is presented. The first chapter explains the basic mechanical theory of heat. Considerable space is devoted in the second chapter to explaining the kinetic theory of gases in order that students may more easily comprehend the subsequent material. The fundamental laws of the science and the simple changes of state are discussed at length in the third chapter.

The book should prove especially valuable not only to the engineering student or instructor who wishes a thorough treatment of the subject but as well to the practicing engineer for purposes of review or reference. It contains 430 pages and the price is $3.75.

Oil Burners

By Kalman Steiner

This is an exhaustive treatise by the chief engineer of the Consumers Petroleum Company of Chicago, embracing a discussion of fundamental and advanced engineering as well as practical methods of oil burner design; also, the characteristics, specifications, combustion and handling of fuel oils. Chapters are devoted to representative domestic, commercial, industrial and power types. Auxiliary equipment such as fans, pumps, piping, strainers, heaters and controls are dealt with in detail, and considerable space is devoted to oil storage and maintenance of equipment. Practical installation data are included. The appendix contains numerous tables of use to the designer of oil-burning installations.

The book contains 436 pages, 6 × 9 in. and over 200 illustrations. Price $4.50.

Current Titles

This is a new monthly publication in which are listed the contents of all the more important English language periodicals of the current month in the fields of engineering, chemistry, physics, geology and technology. The first issue appeared late in October. The January issue of 100 pages includes approximately 2800 article titles from over 200 periodicals published here and abroad. A convenient subject index is provided to enable one to scan readily the titles of current articles in any particular industry.

No attempt is made to present synopses of the articles but, in view of the diversified interests of many engineers and the fact that their problems often involve allied fields, it is believed that this new publication will serve a most useful purpose. It should appeal especially to those who desire to keep informed, yet are not in a position to avail themselves of the more expensive index services.

The addresses of all the magazines are given, so that if the local library does not happen to have a copy, one can be obtained direct; or as an alternative procedure the publisher of "Current Titles" has provided a service

for obtaining copies, photostats or reprints at nominal cost to the subscriber.

The publisher and editor is Arthur C. Stern, 928 Broadway, New York. Subscription price $3 per year.

Symposium on Significance of Tests of Coal

This Symposium gives in convenient form detailed discussions of the meaning of the results of tests of coal, through six extensive technical papers prepared by outstanding authorities at the Fortieth Annual Meeting of the American Society for Testing Materials. In addition to the papers, there is considerable discussion by other technologists. Following the paper on interpretation of laboratory coal tests—proximate analysis and calorific value, there is discussion of the significance of sulphur in coal and also the significance of ash softening temperature and ash composition in the utilization of coal. Laboratory tests relating to caking, plastic, gas- and coke-making properties of bituminous coals and the significance of friability and size stability tests on coal are covered. Pulverizer performance, as affected by grindability of coal and other factors, forms the subject of the sixth paper. In addition to presenting the viewpoints of leading technologists, the publication also gives a large number of bibliographic references.

Bound in heavy paper cover, copies of this 132-page publication can be obtained at $1 each from A. S. T. M. Headquarters, 260 S. Broad St., Philadelphia, Pa.

George Westinghouse

Twenty of the nation's leaders pooled their memories to tell the story of an epic battle that brought electricity into 22,000,000 American homes and paved the way for a giant industry. Their story—the life history of George Westinghouse—is now told in a book published by the American Society of Mechanical Engineers, copies of which are being distributed free upon request by the Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa., as long as the supply lasts.

In a literal sense, the book tells the story of electricity itself; for the author-editor, Charles F. Scott, professor emeritus of electrical engineering at Yale University, and most of his co-writers, were eye-witnesses not only of the struggle for the alternating-current system, but of the coming of the modern high-speed steam turbine, the air-brake, the improved transformer, the air-spring, the electric railway and a hundred other engineering feats associated with the name Westinghouse.

Bearing witness to these successes is an imposing list of co-authors which includes: Dr. James R. Angell, former president of Yale University; Paul D. Cravath; W. L. Batt and the late Ambrose Swasey, past presidents of the A. S. M. E.; Ralph Budd, president of the Burlington Lines; A. W. Berresford and L. B. Stillwell, past presidents of the A. I. E. E.; Frank W. Smith, until recently, president of the Consolidated Edison Company; S. M. Vauclain, chairman of the Baldwin Locomotive Works; and J. V. B. Duer, chief electrical engineer, Pennsylvania Railroad.

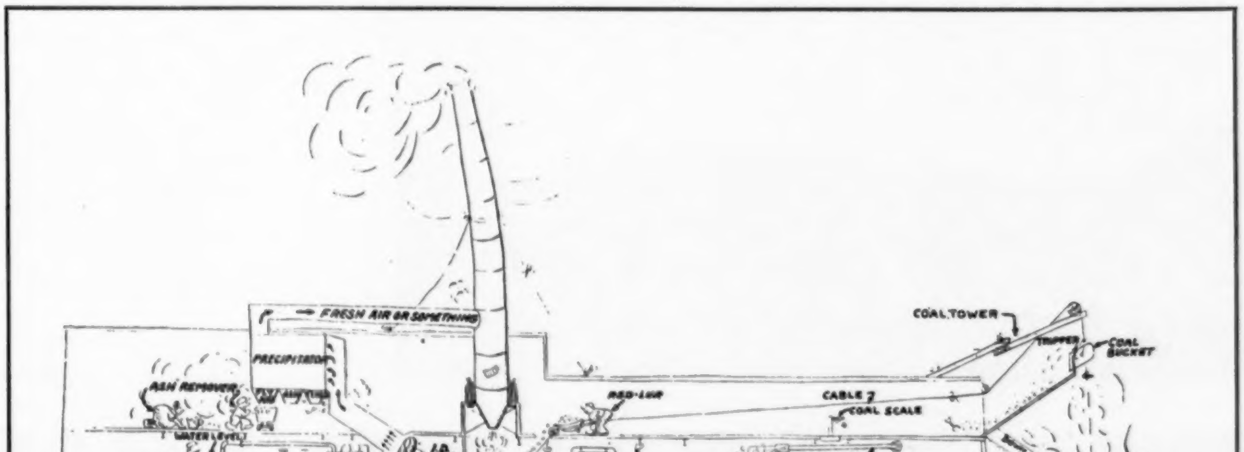
Chief Engineer of Waterside Honored upon Retirement

Two hundred and fifty guests attended a dinner at the Hotel McAlpin, Wednesday evening, January 19, in honor of Foster L. Moore, who is approaching retirement as chief engineer at Waterside Station. H. Y. Hall, Waterside superintendent, as toastmaster, presented a diamond ring to Mr. Moore on behalf of Waterside employees.

On behalf of the Engineering Department, W. J. Angus presented Mr. Moore with a drawing of the Waterside high-pressure installation. This drawing is reproduced herewith, and depicts the state of mind of the engineers after struggling with Mr. Moore to obtain his approval of the several drawings required for the installation.

A Waterside man since 1902, when he joined the old New York Edison Company as a gallery engineer, Mr. Moore has been a licensed engineer since 1891 and a machinist since 1881. His experience has ranged from supervision of arc light dynamos belt driven by a 75-hp steam engine at the Yonkers Electric Company, of which he was chief engineer in the middle 'nineties, to operation of steam equipment included in the latest high-pressure installation at Waterside.

As assistant chief engineer he ordered the oil turned on, had the pumps started and opened the throttle to "roll" the machine when the system's first a.c. turbine-generator swung into action in 1904. Yet he recalls as his "biggest moment" watching George B. Cortelyou start up the station's first 20,000-kw. unit in 1911.



Sketch depicting Waterside operation

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